ML-TDR-64-116

RESEARCH INVESTIGATION TO DETERMINE MECHANICAL PROPERTIES OF NICKEL AND COBALT-BASE ALLOYS FOR INCLUSION IN MILITARY HANDBOOK-5

VOLUME I

TECHNICAL DOCUMENTARY REPORT NO. ML-TDR-64-116

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FOREWORD

This report was prepared by Republic Aviation Corporation, Production Engineering Division under USAF Contract No. AF33(657)-8924. The contract was initiated under Project No. 7381, "Materials' Application", Task No. 738103, "Materials' Information Development, Collection and Processing." The work was administered under the direction of the AF Materials Laboratory, Wright-Patterson Air Force Base, Ohio, by Mr. C. L. Harmsworth, Project Engineer.

This report covers work conducted from April 1961 to June 1964.

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ABSTRACT

The purpose of this program was to develop design information on four nickel and cobalt base alloys for inclusion in Military Handbook-5 The alloys investigated were René 41, L-605, Inconel 702, and Incoloy 901.

The mechanical properties investigated were tensile, compression, shear, bearing, creep, stress-rupture, and fatigue. The general results obtained are presented in Section VII of this report and the data generated for Military Handbook-5 are presented in Section VIII.

The raw data generated in this program is presented in Volume II of this report.

This technical documentary report has been reviewed and is approved.

D. A. SHINN
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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

SECTION I - INTRODUCTION

SECTION 1 - INTRODUCTION

1.1 Purpose of the Program

The program objective was to obtain statistically sound 'A' and 'B' type data on mechanical properties of nickel and cobalt base alloys for inclusion in Military Handbook-5. Three different heats of each aircraft quality alloy material were evaluated. These alloys are:

a.	Rene' 41	AMS 5545 - plate, sheet and strip AMS 5512 - bars and forgings AMS 5513 - bars and forgings
b.	L-605	AMS 5537 - sheet AMS 5759A - bars and forgings
c.	Inconel 702	AMS 5550 - sheet
d.	Incoloy 701	AMS 5660A - bars and forgings

The mechanical property tests performed were tension, compression, bearing, shear, stress-rupture, creep, and fatigue at temperatures ranging from ambient to 1880°F. The data generated was compared with data obtained by means of a literature search.

1.2 Background

Although there have been concentrated research and developmental programs on other more refractory alloys over the last few years, nickel and cobalt base alloys must still be considered paramount for present high temperature, load carrying applications. Most high strength refractory metals are still in the relatively early stages of development and indications from Aerospace Industry are that it probably will be several years before refractory metals and alloys with compatible coatings will be commercially available for general use as primary aerospace structures.

Dependable design criteria for nickel and cobalt base alloys must be considered inadequate in comparison with the more common steels and aluminum alloys. A survey of literature on the mechanical properties of the subject alloys has shown a significant quantity of data but very little standardization. An examination of these data, much of which is producer generated, showed wide latitude in such variables as (1) the stage of development of a particular alloy at the time of testing; (2) heat treat condition of material; (3) difference in nominal composition; (4) sampling procedures;

(5) sample preparation; (6) testing techniques; (7) testing environments; (8) correlation with gauges, sized for sheet, bar and plate; (9) data presentation, and (10) the number of tests used to fix a point on a curve.

The high degree of overall confidence demanded by the Aircraft and Aerospace Industries requires an unprejudiced look at the reliability of design allowable strengths.

SECTION II - SCOPE

SECTION II - SCOPE

2.0 Scope Discussion

The material data contained in Section 2.1 herein provides the pertinent history, source, chemistry, condition, and form for all the materials used in the program. Each material is listed with the applicable specification, vendor's name, and material heat number. The heat treatment condition is briefly described and the mechanical properties as reported in the vendor's test report are also included.

The scope of the test materials program is briefly summarized below as to material, source, and number of vendor heats.

Material	Source	Number of Vendor Heats
Rene' 41	General Electric Company	14
L-605	Haynes Stellite	6
Inconel 702	Huntington Alloy Prod. - Div. of International Nickel Company	3
Incoloy 901	Allvac Metal Company	3

In addition to the data resulting from the test program, data has also been incorporated from Republic's Quality Control Laboratory and test reports of the following vendors:

Cannon-Muskegon Corporation

Universal Cyclops Steel Corporation

Latrobe Steel Corporation

Firth Stirling, Incorporated

International Nickel Company

Section 2.2 lists the mechanical properties that have been determined from each type of test performed.

Section 2.3 discusses briefly the test conditions and contains detailed tables denoting test conditions for each type of test.

Table 1

2.1 Test Materials

2.1.1 Material: Rene' 41

Specification: AMS 5545 - sheet and plate

Specification Minimum Properties

	Gauge	Room Temp.	1400 F
Tensile Strength, ksi	.010	170	130
	.020	170	135
	.040 & up	170	140
Yield Strength, 0.2% offset	All	130	110
Elongation, % in 2 in.	All	10	3

Vendor: General Electric Company, Detroit, Michigan

Vendor Heat Number: R-405
RAC Identification: Heat A

Chemical Composition

Carbon	0.12	Cobalt	11.08
Sulfur	0.005	Titanium	3.18
Silicon	0.07	Aluminum	1.50
Manganese	0.02	Boron	0.0053
Chromium	18.68	Iron	0.30
Molybdenum	9.74	Nickel	Balance

Heat Treat Condition - As Received: 1975°F water quench
1400°F for 16 hours and air cool

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.010 In. Sheet	Room	203.3	165.4	17.0
	1400	154.1	130.1	6.0
0.020 In. Sheet	Room	-	-	-
	1400	-	-	-
0.040 In. Sheet	Room	204.9	159.6	18.0
	1400	164.3	138.3	17.0
0.080 In. Sheet	Room	189.7	156.7	14.0
	1400	164.4	137.8	19.0
*0.375 In. Plate	Room	196.4	147.6	22.4
*	1400	155.3	123.7	9.7
1.00 In. Plate	Room	188.0	134.0	14.7
	1400	150.9	111.8	10.3

*1975°F for 2 hours and water quench 1400°F for 16 hours and air cool

TABLE 1 (cont'd)

Chemical Composition
RAC Identification: Heat B

	Vendor Heat Numbers					
	R-248	R-329-22	R-274-8	R-279	R-402	R-403
Carbon	0.11	0.06	0.06	0.06	0.10	0.10
Sulfur	0.006	0.007	0.006	0.006	0.007	0.006
Silicon	0.08	0.07	0.08	0.06	0.08	0.09
Manganese	0.07	0.03	0.05	0.04	0.03	0.04
Chromium	19.28	18.84	19.09	19.24	18.92	18.98
Molybdenum	9.60	9.75	9.83	9.71	9.83	9.89
Cobalt	10.93	11.04	10.85	10.98	10.93	11.06
Titanium	3.10	3.23	3.14	3.11	3.06	3.13
Aluminum	1.41	1.50	1.44	1.55	1.40	1.42
Boron	0.004	0.004	0.004	0.005	0.004	0.005
Iron	0.30	0.30	0.30	0.30	0.89	1.18
Nickel	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.

Vendor Test Report

Form	Vendor Heat No.	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.010 In. Sheet	R-329-22	Room	199.6	136.9	18.0
		1400	141.2	135.4	4.0
0.020 In. Sheet	R-248	Room	204.9	163.3	20.0
		1400	146.6	121.6	5.0
0.040 In. * Sheet	R-274-8	Room	192.2	134.7	17.0
		1400	156.8	127.9	4.0
0.080 In. Sheet	R-279-4	Room	202.8	159.3	22.0
		1400	158.4	113.4	9.0
**0.375 In. **Plate	R-402	Room	192.2	139.4	32.8
		1400	150.2	112.7	16.1
1.00 In. Plate	R-403	Room	195.8	146.3	23.2
		1400	152.8	121.0	11.6

* 1975°F and water quench 1975°F for 30 mins. and air cool
1400°F for 16 hours and air cool

** 1975°F for 2 hours and water quench 1400°F for 16 hours and air cool

Chemical Composition
RAC Identification: Heat C

Vendors Heat Numbers

	R-254	R-332	R-317	R-274	R-286	R-403	R-402
Carbon	0.08	0.07	0.06	0.06	0.07	0.10	0.10
Sulfur	0.005	0.007	0.007	0.006	0.006	0.006	0.007
Silicon	0.08	0.07	0.07	0.08	0.07	0.09	0.08
Manganese	0.05	0.03	0.01	0.05	0.04	0.04	0.03
Chromium	19.13	18.93	19.04	19.09	19.02	18.98	18.92
Molybdenum	9.82	9.62	9.70	9.83	9.89	9.89	9.83
Cobalt	11.06	11.06	11.06	10.85	11.03	11.06	10.93
Titanium	3.13	3.18	3.14	3.14	3.16	3.13	3.06
Aluminum	1.44	1.54	1.46	1.44	1.47	1.42	1.40
Boron	0.004	0.004	0.0044	0.004	0.005	0.005	0.004
Iron	0.30	0.30	0.30	0.30	0.30	1.18	0.89
Nickel	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.

Vendor Test Report

Form	Vendor Heat No.	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.020 In. Sheet	R-317	Room	201.9	136.3	23.5
		1400	146.9	120.0	3.0
* 0.040 In. Sheet	R-274	Room	192.2	134.7	17.0
		1400	156.8	127.9	4.0
0.080 In. Sheet	R-286	Room	203.3	179.4	21.0
		1400	160.8	136.3	8.0
0.375 In. Plate	R-403	Room	195.0	138.3	32.1
		1400	148.7	116.1	13.5
1.00 In. Plate	R-402	Room	188.0	132.8	19.7
		1400	148.0	110.8	9.3

* 1975°F and water quench   1975°F for 30 mins. and air cool
1400°F for 16 hours and air cool

Table 1 (cont'd)

Material: Rene' 41
Specification: AMS 5713 - bar and forgings
Specification Minimum Properties:

	Room Temp.	1400 F
Tensile Strength ksi	170	135
Yield Strength, 0.2% offset	130	105
Elongation, % in 4D	8	5

Vendor: General Electric Company, Detroit, Michigan

Vendor Heat Number: R-420
RAC Identification: Heat E

Chemical Composition

Carbon	0.09	Cobalt	10.92
Sulfur	0.006	Titanium	3.09
Silicon	0.09	Aluminum	1.50
Manganese	0.03	Boron	0.006
Chromium	18.96	Iron	1.01
Molybdenum	10.02	Nickel	Balance

Heat Treat Condition - As Received 1975°F for 4 hours and water quench
1400°F for 16 hours and air cool

Vendor Test Results

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.500 In. Bar	Room	203.0	155.2	23.0
	1400	166.0	127.0	10.8
1.00 In. Bar	Room	196.8	149.8	21.1
	1400	162.5	122.3	12.2
* 1" x 3" Forging	Room	204.0	154.4	22.4
*	1400	153.4	127.1	9.0

* 1975°F for 2 hours and water quench 1400°F for 16 hours and air cool

Stress Rupture

Form	Test Temp. °F	Stress-KSI	Life-Hours	% Elong.
0.500 In. Bar	1350	85.0	84	32.6
1.000 In. Bar	1350	85.0	103	25.0
1" x 3" Forging	1350	85.0	115	14.3

Vendor Heat Number: R-383
RAC Identification: Heat F

Chemical Composition

Carbon	0.11	Cobalt	11.10
Sulfur	0.006	Titanium	3.09
Silicon	0.08	Aluminum	1.45
Manganese	0.06	Boron	0.0032
Chromium	18.63	Iron	1.46
Molybdenum	9.57	Nickel	Balance

Heat Treat Condition - As Received   1975°F for 4 hours and water quench
1400°F for 16 hours and air cool

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.500 In. Bar	Room	199.5	146.8	22.5
	1400	155.0	119.1	8.0
* 1.00 In. Bar	Room	190.0	141.5	20.7
	1400	155.8	117.5	10.5
1" x 3" Forging	Room	198.0	146.8	21.4
	1400	149.0	119.4	8.7

* 1975°for 2 hours and water quench   1400°F for 16 hours and air cool

Stress Rupture

Form	Temp. °F	Stress-KSI	Life-Hours	% Elong.
0.500 In. Bar	1350	85.0	82	15.9
1.00 In. Bar	1350	85.0	64	5.1
1" x 3" Forging	1350	85.0	92	-

TABLE 1 (cont'd)

Vendor Heat Number: R-410
RAC Identification: Heat G

Chemical Composition

Carbon	0.07	Cobalt	10.98
Sulfur	0.006	Titanium	3.09
Silicon	0.07	Aluminum	1.49
Manganese	0.04	Boron	0.0044
Chromium	19.02	Iron	0.46
Molybdenum	9.94	Nickel	Balance

Heat Treat Condition - As Received   1975°F for 4 hours and water quench
1400°F for 16 hours and air cool

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
* 0.500 In. Bar	Room	196.0	135.5	26.2
	1400	160.6	118.5	11.5
1.00 In. Bar	Room	194.0	144.5	21.5
	1400	163.0	122.0	12.9
* 1" x 3" Forging	Room	203.0	152.2	26.4
	1400	152.5	119.2	9.4

* 1975°F for 2 hours and water quench 1400°F for 16 hours and air cool

Stress Rupture

Form	Temp. °F	Stress-KSI	Life-Hours	% Elong.
0.500 In. Bar	1350	85.0	106	10.7
1.00 In. Bar	1350	85.0	89	10.1
1" x 3" Forging	1350	85.0	67	6.2

Table 2

2.1.2 Material: L-605
Specification: AMS 5537A - Sheet and Plate
Specification Minimum Properties:

Tensile Strength, ksi		130
Yield Strength 0.2% offset, ksi		55-80
Elongation, % in 2 in.	0.020	30
	0.040	40
	over 0.040	45

Vendor: Haynes Stellite Company, Kokomo, Indiana

Vendor Heat Number: L2-1787
RAC Identification: Heat A

Chemical Composition

Chromium	19.91	Nickel	10.34
Tungsten	14.41	Manganese	1.52
Iron	1.97	Phosphorous	0.014
Carbon	0.11	Sulfur	0.010
Silicon	0.48	Cobalt	Balance

Heat Treat Condition - As Received
2250°F for two (2) hours and water quench

Vendor Test Report

Form	Test Temp.°F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.020 In. Sheet	Room	136.95	71.2	45.0
0.040 In. Sheet	Room	136.25	65.25	54.0
0.080 In. Sheet	Room	139.2	66.45	58.0
0.375 In. Plate	Room	-	-	-
1.00 In. Plate	Room	143.55	67.75	60.0

TABLE 2 (cont'd)

Vendor Heat Number: L2-1782
RAC Identification: Heat B

Chemical Composition

Chromium	19.91	Nickel	10.01
Tungsten	14.79	Manganese	1.47
Iron	2.13	Phosphorus	0.015
Carbon	0.10	Sulfur	0.014
Silicon	0.60	Cobalt	Balance

Heat Treat Condition - As Received   2250°F for 2 hours and water quench

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.020 In. Sheet	Room	137.75	72.3	45.0
0.040 In. Sheet	Room	142.8	67.25	55.0
0.080 In. Sheet	Room	140.3	65.25	58.0
0.375 In. Plate	Room	140.0	68.55	55.0
1.00 In. Plate	Room	144.45	67.85	60.0

Vendor Heat Number: L2-1754
RAC Identification: Heat C

Chemical Composition

Chromium	20.85	Nickel	9.91
Tungsten	15.06	Manganese	1.55
Iron	2.17	Phosphorus	0.11
Carbon	0.11	Sulfur	0.18
Silicone	0.58	Cobalt	Balance

Heat Treat Condition - As Received   2250°F for 2 hours and water quench

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.020 In. Sheet	Room	140.1	70.15	46.0
0.040 In. Sheet	Room	144.7	69.4	52.0
0.080 In. Sheet	Room	142.95	69.15	57.0
0.375 In. Plate	Room	140.750	69.0	55.0
1.00 In. Plate	Room	142.5	67.75	62

Table 2 (cont'd)

Material: L-605
Specification: AMS 5759B - Bar and Forgings
Specification Minimum Properties:

Tensile Strength, ksi	125
Yield Strength 0.2% offset, ksi	45
Elongation, % in 4D	30

Vendor: Haynes Stellite Company, Kokomo, Indiana

Vendor Heat Number: L2-1756
RAC Identification: Heat E

Chemical Composition

Chromium	20.53	Nickel	9.84
Tungsten	15.31	Manganese	1.49
Iron	1.97	Phosphorus	0.013
Carbon	0.11	Sulfur	0.012
Silicon	0.51	Cobalt	Balance

Heat Treat Condition - As Received 2250°F for 2 hours and water quench

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.500 In. Bar	Room			
1.00 In. Bar	Room			
1" x 3" Forging	Room	142.1	70.45	58.0

Vendor Heat Number: L2-1729
RAC Identification: Heat F

Chemical Composition

Chromium	20.37	Nickel	9.97
Tungsten	15.08	Manganese	1.40
Iron	1.98	Phosphorus	0.013
Carbon	0.09	Sulfur	0.013
Silicon	0.56	Cobalt	Balance

Heat Condition: As Received 2250°F for 2 hours and water quench

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.500 In. Bar	Room	144.35	69.8	40.0
1.00 In. Bar	Room	141.3	70.0	59.0
1" x 3" Forging	Room	141.5	71.85	61.0

TABLE 2 (cont'd)

Vendor Heat Number: L2-1737
RAC Identification: Heat G

Chemical Composition

Chromium	19.95	Nickel	10.05
Tungsten	14.79	Manganese	1.37
Iron	1.91	Phosphorus	0.012
Carbon	0.10	Sulfur	0.019
Silicon	0.62	Cobalt	Balance

Heat Treat Condition - As-Received

2250°F for 2 hours and water quench

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 1 In.
0.500 In. Bar	Room			
1.00 In. Bar	Room			
1" x 3" Forging	Room	134.85	66.2	60

TABLE 3

2.1.3 Material: Inconel 702

Specification: AMS 5550 - Sheet

Specification Minimum Properties:

Tensile Strength, ksi		125
Yield Strength, 0.2% offset, ksi		60
Elongation, % in 2 in.	0.010	17
	0.020	17
	0.040	25

Vendor: Huntington Alloy Products, Div. Internation Nickel, Huntington, W. Virginia

Vendor Heat Number: HT 5804D
RAC Identification: Heat A

Chemical Composition

Carbon	0.04	Copper	0.06
Manganese	0.07	Chromium	15.35
Iron	0.71	Aluminum	3.02
Sulfur	0.007	Titanium	0.53
Silicon	0.17	Nickel	Balance

Heat Treat Condition - As Received 1975°F for 1/2 hour and air cool
1400°F for 5 hours and air cool

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.010	Room	139.0	80.5	28.0
0.020	Room	141.0	77.0	35.0
0.040	Room			

Vendor Heat Number: HT 5807D
RAC Identification: Heat B

Chemical Composition

Carbon	0.03	Copper	0.06
Manganese	0.06	Chromium	14.64
Iron	0.37	Aluminum	3.10
Sulfur	0.007	Titanium	0.51
Silicon	0.21	Nickel	Balance

Heat Treat Condition - As Received

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.010	Room	136.0	78.0	29.0

TABLE 3 (cont'd)

Vendor Heat Number: HT 5806D
RAC Identification: Heat C

Chemical Composition

Carbon	0.04	Copper	0.07
Manganese	0.06	Chromium	14.80
Iron	0.37	Aluminum	2.99
Sulfur	0.007	Titanium	0.52
Silicon	0.18	Nickel	Balance

Heat Treat Condition - As Received

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 2 In.
0.010	Room	134.0	79.0	26
0.040	Room	143.0	85.0	35

TABLE 4

2.1.4 Material: Incoloy 901

Specification: AMS 5660A - Bar and Forgings

Specification Minimum Properties:

Tensile Strength, ksi	150
Yield Strength, 0.2% offset, ksi	100
Elongation, % in 4D	12

Vendor: Allvac Metals Company, Monroe, North Carolina

Vendor Heat Number: 5036
RAC Identification: Heat E

Chemical Composition

Carbon	0.066	Titanium	2.67
Sulfur	0.012	Aluminum	0.13
Manganese	0.05	Boron	0.013
Silicon	0.06	Copper	0.05
Chromium	12.41	Nickel	43.20
Molybdenum	6.14	Phosphorus	0.01
Cobalt	0.18	Iron	Balance

Heat Treat Condition - As Received: 2000°F for 2 hours and water quench
1450°F for 2 hours and air cool
1325°F for 24 hours and air cool

Hardness: Rc 35-38

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 1.0 In.	Hardness Tested Rc
0.500 In. Bar	Room	182.5	116.0	19.8	34
1.00 In. Bar	Room	182.5	116.0	19.8	34
1" x 3" Forging	Room	169.9	111.6	19	32.5

Stress Rupture

Test Specimen: 0.252 in comb. smooth and notched bar

Form	Test Temp. °F	Stress-KSI	Life Hours	% Elong.-1.0 In.
0.500 In. Bar	1200	80.0	190.4	28
1.00 In. Bar	1200	80.0	190.2	28.1
1" x 3" Forging	1200	80.0	128.4	20.0

TABLE 4 (cont'd)

Vendor Heat Number: 3164
RAC Identification: Heat F

Chemical Composition

Carbon	0.061	Titanium	2.95
Sulfur	0.008	Aluminum	0.22
Manganese	0.06	Boron	0.014
Silicon	0.08	Copper	0.04
Chromium	12.26	Nickel	43.25
Molybdenum	6.20	Phosphorus	0.007
Cobalt	0.08	Iron	Balance

Heat Treat Condition - As Received

2000°F for 2 hours and water quench
1450°F for 2 hours and air cool
1325°F for 24 hours and air cool

Hardness: Rc 32-37.5

Vendor Test Report

Form	Test Temp.°F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 1.0 In.	Hardness Tested Rc
0.500 In.Bar	Room	185.0	120.3	14.0	36
1.00 In. Bar	Room	185.0	120.3	14.0	36
1"x3" Forging	Room	183.1	127.4	18.4	37.5

Stress Rupture

Test Specimen: 0.252 comb. smooth and notched bar

Form	Test Temp.°F	Stress-KSI	Life Hours	% Elong. 1.0 In.
0.500 In. Bar	1200	80.0	158.9	16
1.00 In. Bar	1200	80.0	158.9	16
1 " x 3" Forging	1200	80.0	495.7	5.1 Did not fail

TABLE 4 (cont'd)

Vendor Heat Number: 3192
RAC Identification: Heat G

Chemical Composition

Carbon	0.057	Titanium	2.60
Sulfur	0.009	Aluminum	0.23
Manganese	0.05	Boron	0.018
Silicon	0.03	Copper	0.05
Chromium	12.28	Nickel	42.68
Molybdenum	6.10	Phosphorus	0.007
Cobalt	0.12	Iron	Balance

Heat Treat Condition - As Received: 2000°F for 2 hours and water quench; 1450°F for 2 hours and air cool; 1325°F for 24 hours and air cool

Hardness: Rc 33-34

Vendor Test Report

Form	Test Temp. °F	Ult. Tensile Strength-KSI	0.2% Yield Strength-KSI	% Elong. 1.0 In.	Hardness Tested-Rc
0.500 In. Bar	Room	167.2	109.3	22.0	32.5
1.00 In. Bar	Room	167.2	109.3	21.6	32.5
1" x 3" Forging	Room	164.5	103.5	21.0	30.5

Stress Rupture

Test Specimen: 0.252 comb. smooth and notched bar

Form	Temp. °F	Stress-KSI	Life Hours	% Elong. 1.0 In.
0.500 In. Bar	1200	80	102	26.0
1.00 In. Bar	1200	80	102	25.6
1" x 3" Forging	1200	80	108	19.0

2.2 Mechanical Properties Determined

The various mechanical properties determined from each type of test performed are as follows:

1. Tensile Tests - Sheet and Bar
   a. Ultimate tensile strength
   b. Tensile yield strength
   c. Elongation
   d. Modulus of elasticity

2. Compression Tests - Sheet and Bar
   a. Compression yield strength
   b. Modulus of elasticity

3. Bearing Tests of Sheet - $e/D = 1.5$ and $e/D = 2$
   a. Ultimate bearing strength
   b. Bearing yield strength

4. Shear Tests - Sheet and Bar
   a. Ultimate shear strength

5. Creep - Sheet and Bar
   a. Percent deformation versus time as a function of temperature and stress

6. Stress-Rupture - Sheet and Bar
   a. Time to fracture as a function of temperature and stress

7. Fatigue
   a. Stress versus number of cycles to failure, as a function of temperature and stress-ratio

2.3 Test Conditions

Room and elevated temperature, tension, compression, bearing, and shear mechanical property data for both the longitudinal and transverse directions for each material in air atmosphere. The range of elevated temperature data was from 400°F to 1800°F, in increments of 200°F. Data on the effects of exposure in air at temperatures from 400°F to 1800°F for times of 10, 100, 500, and 1000 hours, were compiled from tests at exposure temperature and at room temperature after exposure.

Creep test data was obtained at temperatures 1000°F through 1800°F in air atmosphere. Sheet test specimens were in the transverse direction only. Creep deformations of 0.05, 0.1, 0.3, 0.5 and 1% were obtained.

Stress-rupture data was compiled at temperatures of 400°F through 1800°F, and for lives of 0.1, 1, 100, and 1000 hours.

Axial fatigue test data was obtained at room temperature, and at elevated temperatures from 400°F to 1800°F in increments of 200°F. The data includes lives of 100 cycles through 10^7 cycles, and at stress ratios of $A = \infty$, 2.0, 0.98, 0.67, and 0.25 where:

$$A = \frac{\text{Alternating Stress}}{\text{Mean Stress}}$$

All alloy materials under this contract were tested in the "as received" conditions (described in Section II - Test Materials), except Rene' 41 AMS 5712. Finished test specimens were fabricated from the AMS 5712 alloy material, and subsequently aged at 1400°F for 16 hours and air cooled prior to testing. In all other instances, with the exception of exposure tests, there was no further thermal processing.

Test conditions for the complete program are shown in Tables 5 through 16.

TABLE 5

TENSION TESTS

Material	Size and Form	70[1]	400	600	800	1000	1200	1400	1600	1800	Tests Per Alloy
		Number of Tests Per Temperature									
Rene' 41 (AMS 5545) and L-605 (AMS 5537)	.005 Strip	60*	-	10*	-	10*	-	10*	-	10*	100
	.010 Sheet	60*	-	10*	-	10*	-	10*	-	10*	100
	.020 Sheet	60*	-	10*	-	10*	-	10*	-	10*	100
	.040 Sheet	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
	.080 Sheet	60*	-	-	-	10*	-	10*	-	10*	90
	.375 Plate	60*	-	-	-	10*	-	10*	-	10*	90
	1.000 Plate	60*	-	-	-	-	-	10*	-	-	70
Rene' 41 (AMS 5713) and L-605 (AMS 5759)	0.5 Bar	15	-	5	-	5	5	5	5	5	45
	1.0 Bar	15	-	-	-	5	-	5	-	5	30
	1x3 Forging	30*	-	-	-	-	-	10*	-	-	40
Rene' 41 (AMS 5712)	0.5 Bar	15	-	5	-	5	5	5	5	5	45
	1.0 Bar	15	-	-	-	-	-	-	-	-	15
	1x3 Forging	30*	-	-	-	-	-	-	-	-	30
Incoloy 901 (AMS 5660)	0.5 Bar	30	5	5	5	5	5	5	5	5	70
	1.0 Bar	30	-	5	-	5	-	5	-	5	50
	1x3 Forging	60*	-	-	-	10*	-	10*	-	10*	90
								Total Tension Tests			1910

1 Tests are equally divided between three heats of material.

* Half of these tests are in the transverse direction. All other tests are in longitudinal direction.

TABLE 6

COMPRESSION TESTS

Material	Size and Form	70[1]	400	600	800	1000	1200	1400	1600	1800	Tests Per Alloy
		Number of Tests Per Temperature									
Rene' 41	.020 Sheet	60*	-	-	-	-	-	-	-	-	60
(AMS 5545)	.040 Sheet	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
and L-605	.080 Sheet	60*	-	-	-	10*	-	10*	-	-	80
(AMS 5537)	.375 Plate	60*	-	-	-	10*	-	10*	-	-	80
Rene' 41	0.5 Bar	15	-	-	-	5	-	-	-	5	25
(AMS 5713)	1.0 Bar	15	-	5	-	5	-	5	-	5	35
and L-605	1 x 3 Forging	30*	-	-	-	10*	-	-	-	10*	50
(AMS 5759)											
Rene' 41	0.5 Bar	15	-	-	-	-	-	-	-	-	15
(AMS 5712)	1.0 Bar	15	-	5	-	5	-	5	-	5	35
	1 x 3 Forging	30*	-	-	-	-	-	-	-	-	30
Incoloy 901	0.5 Bar	30	-	-	-	5	-	5	-	5	45
(AMS 5660)	1.0 Bar	30	5	5	5	5	5	5	5	5	70
	1 x 3 Forging	60*	-	-	-	10*	-	-	-	10*	80

Total Compression Tests 1215

1 Tests are equally divided between three heats of material.

* Half of these tests are in the transverse direction. All other tests are in the longitudinal direction.

TABLE 7

BEARING TESTS

Material	Thickness	e/D	70°F[1]	400°F	600°F	800°F	1000°F	1200°F	1400°F	1600°F	1800°F	Total
Rene' 41	.020	1.5	30	-	-	-	3	-	3	-	3	39
(AMS-5545	.040	1.5	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
+ Age)	.080	1.5	30	-	-	-	3	-	3	-	3	39
	.375	1.5	30	-	-	-	3	-	3	-	3	39
	.020	2.0	30	-	-	-	3	-	3	-	3	39
	.040	2.0	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
	.080	2.0	30	-	-	-	3	-	3	-	3	39
	.375	2.0	30	-	-	-	3	-	3	-	3	39
L-605	.020	1.5	30	-	-	-	3	-	3	-	3	39
(AMS-5537A)	.040	1.5	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
	.080	1.5	30	-	-	-	3	-	3	-	3	39
	.375	1.5	30	-	-	-	3	-	3	-	3	39
	.020	2.0	30	-	-	-	3	-	3	-	3	39
	.040	2.0	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
	.080	2.0	30	-	-	-	3	-	3	-	3	39
	.375	2.0	30	-	-	-	3	-	3	-	3	39
									Total Bearing Tests			1028

1 Tests are divided between three (3) heats of material at 70°F.

* Half of these tests are in the longitudinal direction, all others in transverse direction.

TABLE 8

SHEAR TESTS

Material	Size and Form	70[1]	400	600	800	1000	1200	1400	1600	1800	Tests Per Alloy
		Number of Tests Per Temperature									
Rene' 41	.020 Sheet	60*	-	5	-	5	-	5	-	5	80
(AMS 5545)	.040 Sheet	60*	5	5	5	5	5	5	5	5	100
and L-605	.080 Sheet	60*	-	5	-	5	-	5	-	5	80
(AMS 5537)	.375 Plate	60*	-	5	-	5	-	5	-	5	80
Rene' 41	0.5 Bar	15	5	5	5	5	5	5	5	5	55
(AMS 5713)	1.0 Bar	15	-	-	-	-	-	-	-	-	15
and L-605	1 x 3 Forging	30*	-	5	-	5	-	5	-	5	50
(AMS 5759)											
Incoloy 901	0.5 Bar	30	5	5	5	5	5	5	5	5	70
(AMS 5660)	1.0 Bar	30	5	5	5	5	5	5	5	5	70
	1 x 3 Forging	30*	-	5	-	5	-	5	-	5	50
							All Alloys - Grand Total				1110

1 Tests are equally divided between three heats of material.

* Half of these tests are in transverse direction. All other tests are in longitudinal direction.

TABLE 9

ELEVATED TEMPERATURE CREEP TESTS

Material	Size and Form	Number of Tests Per Temperature[1] 1000	1200	1400	1600	1800	Total Per Material
Rene' 41 (AMS 5545)	.005 Sheet	4	4	4	4	4	
	.020 Sheet	-	-	4	-	4	
	.040 Sheet	4	4	4	4	4	
	.080 Sheet	-	-	4	-	4	56
L-605 (AMS 5537)	.005 Sheet	4	4	4	4	4	
	.020 Sheet	-	-	4	-	4	
	.040 Sheet	4	4	4	4	4	
	.080 Sheet	-	-	4	-	4	56
Rene' 41 (AMS 5713)	0.5 Bar	4	4	4	4	4	
	1 x 3 Forging	-	-	4*	4*	4*	32
L-605 (AMS 5759)	0.5 Bar	4	4	4	4	4	
	1 x 3 Forging	-	-	4*	4*	4*	32
Incoloy 901 (AMS 5660)	0.5 Bar	4	4	4	4	4	
	1 x 3 Forging	-	-	4*	4*	4*	32
				Total			208
				1 Plus Data from SR			56
				Grand Total			264

1 All data to be used for plotting of Larson-Miller curves from which the desired data will be replotted.
All S-R tests that are intended to last for 1000 hours (approx. 36 tests) will also record creep data. Approximately 20 other S-R tests will also record creep data.

* Half of these tests are in the transverse direction. All other tests in longitudinal direction.

TABLE 10

STRESS-TO-RUPTURE TESTS

Material	Size and Form	Total Specimens Per Temperature[1] 400	600	800	1000	1200	1400	1600	1800	Total Per Material
Rene' 41 (AMS 5545)	.005 Sheet	-	2	2	4	4	6	6	6	
	.020 Sheet	-	2	2	4	4	6	6	6	
	.040 Sheet	8	8	8	8	24	48*	24	48*	
	.080 Sheet	-	2	2	4	4	12*	6	12*	278
L-605 (AMS 5537)	.005 Sheet	-	2	2	4	4	6	6	6	
	.020 Sheet	-	2	2	4	4	6	6	6	
	.040 Sheet	8	8	8	8	24	48*	24	48*	
	.080 Sheet	-	2	2	4	4	12*	6	12*	278
Rene' 41 (AMS 5713)	0.5 Bar	-	2	2	4	4	6	6	6	
	1.0 Bar	-	-	-	-	-	6	-	6	
	1 x 3 Forging	-					12*		12*	66
L-605 (AMS 5759)	0.5 Bar	-	2	2	4	4	6	6	6	
	1.0 Bar	-	-	-	-	-	6	-	6	66
	1 x 3 Forging	-					12*		12*	
Incoloy-901 (AMS 5660)	0.5 Bar	8	8	8	8	24	24	24	24	
	1.0 Bar	-	-	-	-	-	6	-	6	
	1 x 3 Forging	-					12*		12*	164
									Grand Total	852

1 The .040 sheet material of each sheet alloy and the 0.5 diameter Incoloy 901 bar will be tested at 4 load levels at 400, 600, 800, and 1000°F with 2 tests per load level at 8 load levels at 1200, 1400, 1600, and 1800°F with 3 tests per load level. The eight load levels will be adjusted to ideally produce failure in the following times: 0.1, 0.3, 1.0, 3.0, 10.0, 30.0, 100, and 1000 hours. Those materials tested at 4 load levels at one temperature will adjust to fail in 10, 30, 100, and 1000 hours. The balance of testing will be for determining Larson-Miller curves.

* Half of these tests will be in the transverse direction. All other tests in the longitudinal direction.

TABLE 11 - FATIGUE TESTS

MATERIAL	Gauge (Inches)	STRESS RATIO	LOAD LEVELS PER TEMPERATURE °F (See Note 1) 70	400	600	800	1000	1200	1400	1600	1800	TOTALS
Rene' 41	0.040 Sheet	0.98	(21)		3		3		3		3	
AMS 5545 - Aged		0.67	6	4	3	4	3	4	3	4	3	
		0.25	6		2		4*	4*	4*		2	361
Rene' 41	0.080 Sheet	0.67	6			3		3		3		
AMS 5545 - Aged		0.25	6			(15)		(15)		(15)		150
Rene' 41	1.000 Bar		3				3			3		
AMS 5713		0.67	(29)	(22)		4		4		(21)		157
L-605	0.040 Sheet	0.98	(22)		1		1		1		1	
AMS 5537A		0.67	6	2	1	2	1	2	1	2	1	
		0.25	6		1		2	2	2		1	202
L-605	0.080 Sheet	0.67	(27)			1		1		1		
AMS 5537A		0.25	(27)			1		1		1		84
L-605-AMS 5559A	1.000 Bar	0.67	6	2		2		2		2		70
Incoloy 901	1.000 Bar		6		3		3		3		3	
AMS 5660A		2.000	6		3		3		3		3	
		0.98	5		3		3		3		3	
		0.67	6	4	3	4	6*	9*	6*	4	3	490
Inconel 702	0.040 Sheet	0.98	6		2		2		2		2	
AMS 5550		0.67	5	2	1	2	1	2	1	2	1	
		0.25	6		1		2	2	2		1	225
										TOTAL TESTS		1739

NOTE 1: Five tests per load level, except numbers enclosed in parenthesis, which indicate actual number of tests.

* Indicates region where 1800 CPM and 3600 CPM will be investigated.

TABLE 12

EXPOSURE TESTS

Test[2] Type	Material[1] & Form	Time and Temperatures 10	100	500	1000	Tests/Alloy R.T.	Exp.T	Minimum Total Tests R.T.	Exp.T
Tension	.005 Sheet	1800	1800	1800	1800	12	12	24	24
	(René 41)	1600	1600	1600	1600	12	12	24	24
	(L-605)		1400	1400	1400	9	9	18	18
				1200	1200	6	6	12	12
	.040 Sheet	1800	1800	1800	1800	12	12	36	36
	(René 41)	1600	1600	1600	1600	12	12	36	36
	(L-605) &			1400	1400	6	6	18	18
					1200	3	3	9	9
	0.5 Bar				1000	3	3	9	9
	(Incoloy				800	3	3	9	9
	901)				600	3	3	9	9
					400	3	3	9	9
	.080 Sheet		1800	1800	1800	9	9	18	18
			1600	1600	1600	9	9	18	18
					1400	3	3	6	6
Compression	.040 Sheet	1800	1800	1800	1800	12	12	24	24
	(René 41)		1600	1600	1600	9	9	18	18
	(L-605)				1400	3	3	6	6
					1200	3	3	6	6
Shear	.040 Sheet	1800	1800	1800	1800	12	12	24	24
	(René 41)		1600	1600	1600	9	9	18	18
	(L-605)				1400	3	3	6	6
					1200	3	3	6	6
	.080 Sheet	1800	1800	1800	1800	12	12	24	24
	(René 41)		1600	1600	1600	9	9	18	18
	(L-605)				1400	3	3	6	6
					1200	3	3	6	6
Bearing (e/d=1.5)	.040 Sheet	1800	1800	1800	1800	12	12	24	24
	(René 41)		1600	1600	1600	9	9	18	18
	(L-605)				1400	3	3	6	6
					1200	3	3	6	6
	.080 Sheet	1800	1800	1800	1800	12	12	24	24
	(René 41)		1600	1600	1600	9	9	18	18
	(L-605)				1400	3	3	6	6
					1200	3	3	6	6

	R.T.	Exp. Temp.
Total Tension Test	255	255
Total Compression Tests	54	54
Total Shear Tests	108	108
Total Bearing Tests	108	108
MINIMUM TOTAL TESTS	525	525

TABLE 12 (cont'd)

1
- Rene' 41 tested as AMS5545 Age
- L-605 tested as AMS5537A
- Incoloy 901 tested as AMS5660A

2
- All tests in the transverse direction

TABLE 13

STATIC PROPERTIES OF INCONEL 702

SIZE & SHAPE	Number of Tests Per Temperature									
	70°F[1]	400°F	600°F	800°F	1000°F	1200°F	1400°F	1600°F	1800°F	TOTAL
TENSION:										
.005 Strip	60*	-	10*	-	10*	-	10*	-	10*	100
.020 Sheet	60*	-	10*	-	10*	-	10*	-	10*	100
.040 Sheet	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
							TOTAL TENSION			340
COMPRESSION:										
.020 Sheet	60*	-	-	-	-	-	-	-	-	60
.040 Sheet	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
							TOTAL COMPRESSION			200
SHEAR:										
.020 Sheet	60*	-	5	-	5	-	5	-	5	80
.040 Sheet	60*	5	5	5	5	5	5	5	5	100
							TOTAL SHEAR			180
BEARING:										
(e/D = 1.5)										
.020 Sheet	30	-	-	-	3	-	3	-	3	39
.040 Sheet	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
(e/D = 2.0)										
.020 Sheet	30	-	-	-	3	-	3	-	3	39
.040 Sheet	60*	10*	10*	10*	10*	10*	10*	10*	10*	140
							TOTAL BEARING			358

[1] All room temperature tests are equally divided between three (3) heats of material with the exception of the bearing tests on .020" sheet.

* Half of tests in transverse direction. All others in longitudinal direction.

TABLE 14

EXPOSURE TESTS ON INCONEL 702[1]

TYPE OF TEST	SIZE & SHAPE	TIME & TEMPERATURE[2] 10	100	500	1000	SPECIMENS TO BE TESTED R.T.	Exp. T.
TENSION:	.005 Strip	1800	1800	1800	1800	12	12
		1600	1600	1600	1600	12	12
			1400	1400	1400	9	9
				1200	1200	6	6
	.040 Sheet	1800	1800	1800	1800	12	12
		1600	1600	1600	1600	12	12
				1400	1400	6	6
					1200	3	3
					1000	3	3
					800	3	3
					600	3	3
					400	3	3
COMPRESSION:	.040 Sheet	1800	1800	1800	1800	12	12
			1600	1600	1600	9	9
					1400	3	3
					1200	3	3
SHEAR:	.040 Sheet	1800	1800	1800	1800	12	12
			1600	1600	1600	9	9
					1400	3	3
					1200	3	3
BEARING: (e/D = 1.5)	.040 Sheet	1800	1800	1800	1800	12	12
			1600	1600	1600	9	9
					1400	3	3
					1200	3	3
		TOTAL EXPOSURE				165 R.T.	165 Exp. T.

1 - All tests in longitudinal direction.

TABLE 15

CREEP TESTS ON INCONEL 702[1]

SIZE & FORM	1000°F	1200°F	1400°F	1600°F	1800°F	TOTALS
.005 Sheet	4	4	4	4	4	20
.020 Sheet	-	-	4	-	4	8
.040 Sheet	4	4	4	4	4	20

TOTAL CREEP	48
PLUS DATA FROM S.R.	13
GRAND TOTAL	61

TABLE 16

STRESS-RUPTURE TESTS ON INCONEL 702[1]

SIZE & FORM	Number of Tests Per Temperature								
	400°F	600°F	800°F	1000°F	1200°F	1400°F	1600°F	1800°F	TOTALS
.005 Sheet	-	2	2	4	4	6	6	6	30
.020 Sheet	-	2	2	4	4	6	6	6	30
.040 Sheet	8	8	8	8	24	48*	24	48*	176
						TOTAL STRESS-RUPTURE			236

1 The .040 sheet material will be tested at four load levels at 400, 600, 800 and 1000°F with two tests per load level and at eight load levels at 1200, 1400, 1600 and 1800°F with three tests per load level. The eight load levels will be adjusted to ideally produce failure in 0.1, 0.3, 1.0, 3.0, 10.0, 30.0, 100 and 1000-hours. The four load levels at 400 to 1000°F will be adjusted to fail in 10, 30, 100 and 1000-hours. The remainder of the tests will be used to determine Larson-Miller curves.

* Half of these tests will be in the transverse direction.

All others are tested longitudinally.

SECTION III - TEST SPECIMENS

SECTION III - TEST SPECIMENS

3.1 Specimen Identification Codes

Two typical specimen identification numbers are E5LAX-5G and R4TBYE-2H. In general, code numbers will have the above form with each letter or number having a specific meaning as indicated below. The only exception to this system, also described below, involves the two letters immediately following the L or T direction notation (in examples above, AX and BY).

3.1.1 The initial E or R indicates the testing temperature level intended for the specimen (E - elevated, and R - room).

3.1.2 The number following the E or R indicates the type of test; for sheet material, the numbers are as follows:

1 -	Tension
2 -	Stress to rupture
3 -	Creep
4 -	Compression
5 -	Shear
6 -	Bearing with 1.5 edge distance
67 -	Bearing with 2.0 edge distance
7 -	Fatigue

3.1.3 The letter following the type of test number indicates the specimen direction:

L -	Longitudinal
T -	Transverse

3.1.4 The two letters following the directional letter give the material used and the heat from which the specimen was taken. This information is given in one sequence for plate, bar, and forgings, and in the reverse sequence for sheet specimens.

a. Plate, Bar, Forgings - The first of the two letters gives the material, and the second shows the heat.

1) Material Code

A	L605	AMS 5537 (Sheet)
B	L605	AMS 5759 (Bar)
C	Rene' 41	AMS 5545
D	Rene' 41	AMS 5512
E	Rene' 41	AMS 5513
G	Incoloy 901	AMS 5560

2) Heat Code

S Heat A
V Heat B
W Heat C
X Heat E
Y Heat F
Z Heat G

b. Sheet (through .080 inch) - The first of the two letters gives the heat and the second indicates the material.

1) Heat Code

A Heat A
B Heat B
C Heat C

2) Material Code

X L605
Y Rene 41
Z Inconel 702

3.1.5 Exposure notation - where exposure is required prior to testing, a letter E is included following the material-heat or heat-material designation (Example - R6TAXE-3G or E7LASE-5H).

3.1.6 The final number (immediately following the hyphen) indicates the specimen location on the sheet from which the specimen was taken.

3.1.7 The final letter (G and H in the initial examples shown) indicates the sheet used within a given heat. When a heat contained more than one sheet, letter designations were arbitrarily assigned to differentiate one sheet from another.

a. The absence of the sheet designation indicates the particular specimens involved was taken from a heat represented by one sheet (Example- R1LAX-2).

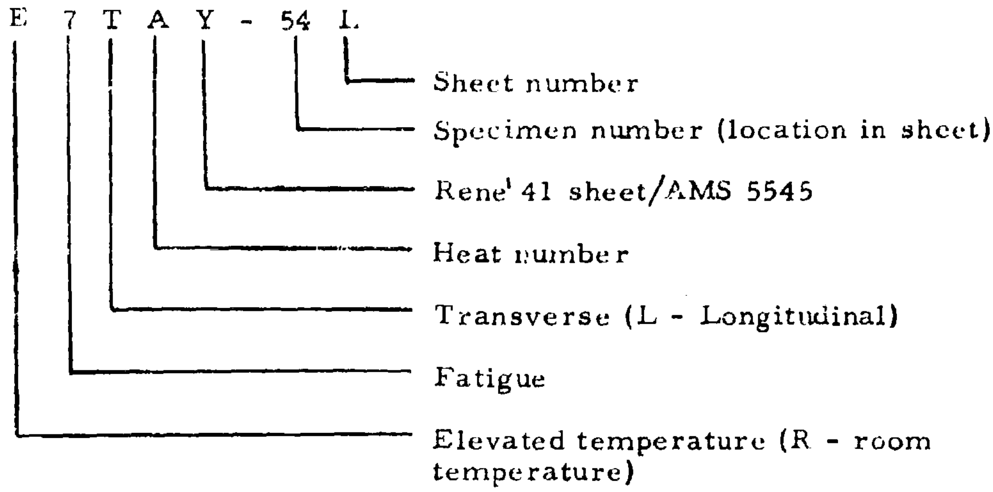
3.1.8 Miscellaneous notations - where duplication of numbers under the standard coding system can occur due to similar specimens received from the same material (same specimen from 1 inch plate or 1 inch bar - or same specimen from 1/2 inch bar or from forging), a further breakdown is made by including a notation in front of the standard code.

a. F indicates specimen was made from a forging (Ex. FR1LBX-2).

b. Number and letter indicate size and type of stock (Ex. 1PE5LAX-2) 1P - 1 inch plate; 3/8P - 3/8 inch plates; 1/2B - 1/2 inch bar; etc.

c. Absence of an extra notation generally means that no duplication of codes can occur.

d. An example of the coding system is shown in the diagram below.



3.2 Specimen Sampling

A typical example of controlled randomization of test specimen sampling for sheet material is shown in Figure 1* . The material is 0.040 inch Rene' 41 sheet, 36 x 96 inches. Oversize specimen blanks were sheared in groups, with each group consisting of at least one specimen for each type of test, in order that the test results would reflect any material property variation within a sheet. Test specimens were taken from both transverse and longitudinal directions for all sheet, plate, and 1 x 3 inch forgings. The 0.500 and 1.00 inch diameter bar were sampled in the longitudinal direction only. Controlled sampling was carried out for each of the three representative heats, and for all gauges of each of four alloy materials.

3.3 Specimen Design

Specimen designs used are shown in Figures 2 through 11*. All test specimens are full size, and conform where applicable to ASTM Standards and Aerospace Industries Association Report No. ARTC-13.

3.4 Specimen Preparation

In an effort to obtain uniformity in test results and to insure that the variations in test results would be due to material properties, the various types of test specimens were machined to close tolerances. The conditions for machining and grinding were chosen to provide a minimum of distortion and residual stress.

* Asterisk - Ref. Section V - Test Procedures

SECTION IV - TEST EQUIPMENT

SECTION IV - TEST EQUIPMENT

4.1 Static Tests

a. Loading Apparatus

The loading apparatus used in the performance of tension, compression, bearing, and shear tests, are as follows:

One - Instron Universal Testing Machine - 10,000 pounds capacity
One - Riehle Universal Testing Machine - 20,000 pounds capacity
Seven - Baldwin-Lima-Hamilton Universal Testing Machines of 50,000, 60,000, 100,000, 120,000 and 150,000 pounds capacity.

All of the above mentioned machines are equipped with strain-rate pacers, and Baldwin-Lima-Hamilton Type MA-1 autographic recorders.

b. Extensometers

Baldwin-Lima-Hamilton Type T-1M and PSH-8MS nicro-former type extensometers were used in conjunction with Type MA-1 autographic recorders to measure load versus deformation.

c. Furnaces

Static test specimens (with the exception of 0.005 and 0.010 inch gauge tensile specimens) were heated by Marshall or Arcweld Type F-6 furnaces with a core 16 inches long and 3 inches in diameter. Split-type three-zone Marshall furnaces 16 inches long and 3 inches in diameter were used to accommodate the larger test fixtures and jigs required for compression and bearing testing. The 0.005 and 0.010 inch gauge sheet tensile specimens were heated by the specimen's electrical resistance. A Thermac Voltage Controller, with a Vernier controlled variable output was used in conjunction with Leeds-Northrup Potentiometers to control and record temperatures. Either Minneapolis-Honeywell Brown Electronik or Leads and Northrup dual range multipoint controller-recorders with 20 A.W.G. diameter chromel-alumel thermocouples, were used to monitor temperature for the furnace heated test specimens.

4.2 Creep and Stress-Rupture Tests

A simple beam loading type test frame having a maximum lever arm ratio of 20 to 1 was used for loading creep specimens. The electrical resistance furnaces were designed by the New England Material Laboratory,

with an 18 inch long alundum core wound with nichrome wire with the upper lower halves controlled. An inner 'shielding tube' was incorporated into the furnace for the purpose of smoothing out hot spots. The furnaces were constructed with nichrome wire wound window tubes also rheostat controlled, through which creep measurements were made. Three chromel-alumel thermocouples were wired to gauge section of test specimen, and specimen temperature was maintained by Minneapolis-Honeywell Brown Electronik controller-recorders.

Creep measurements were made optically by means of a platinum wire-in-tube arrangement mounted on the shoulders of the test specimen.

4.3 Fatigue Tests

A total of nine Universal fatigue testing machines were used; two each Baldwin SF-10-U, SF-11U, and 1V-4F machines were used for the 1800 CPM tests, and one Wiedemann-Baldwin SF-4 for the 3600 CPM tests. All machines were equipped with 5-1 multipliers and constant load maintainers.

Furnaces were either Marshall split type or heavy duty type MK-4010, electrical resistance type with 2200°F capability. Temperature recorder-controllers were Minneapolis-Honeywell Brown Electronik or Leads and Northrup.

4.4 Thermal Processing Equipment

The furnace equipment used for heat-treating and the elevated temperature exposure of test specimens in air is as follows:

One - Pereny Model EX-9-SP-103
One - Precision Model 31281
One - Blue M Model CHH-16
One - Lindberg Model B-6
Two - Temco Model 1525
Two - Dyna-Trol Model P93H

Temperature surveys were made of all furnaces prior to use. Test specimens were always located in the central portion of a furnace where the exposure temperature could be maintained at $\pm$ 10°F.

SECTION V - TEST PROCEDURES

Tables	None
Figures	1 thru 32 (SPC.5.8, page 51)

SECTION V - TEST PROCEDURES

5.1 Tensile Tests

Tensile tests were performed on Instron, Riehle, and Baldwin-Lima-Hamilton Universal testing machines equipped with integral automatic strain pacers, see Figures 12 and 13. Each testing machine was calibrated periodically to insure loading accuracy within ± 0.2% on all scales, in compliance with applicable ASTM Standards and the Aircraft Industries Association Report ARTC-13 specifications for loading accuracy and axiality. Shackles and grips were designed to give load concentricity within 0.003 inches.

Specimens tested at elevated temperatures were generally heated by means of resistance wound (Arcweld and Marshall) furnaces of 2200°F capability and with a 16 inch long core which was 3 inches in diameter. Each furnace was equipped with a (Wheelco) pyrometer with 0 to 2400°F range capable of maintaining ± 5°F over a 2 inch gauge length, and a (Honeywell Brown "Electronik") dual range multipoint recorder with an accuracy of ± 10°F through 1800°F range. An exception was made in the case of the foil gauge specimens, which were heated by the electrical resistance method.

Specimen temperature measurement was by means of 20 A.W.G. diameter chromel-alumel thermocouples attached to the center of test specimen. All thermocouples were checked to a standard calibrated by the National Bureau of Standards. When potentiometers were used, they were calibrated daily to insure accuracy within the standard specifications.

Measurements for area determination were made with a micrometer suitable for measuring to ± 0.0001 inch of the nominal dimension. The average of a minimum of five (5) readings spaced over the gauge length was used to determine the thickness of each test specimen.

Strain measurement was by means of an extensometer attached to the gauge length of a specimen. Since yield strength and the modulus of elasticity were determined for each specimen, a Baldwin-Lima-Hamilton Type T-1M or PSH-8MS Class B-1 extensometer was used in conformance with ASTM Standard E83-57T. The extensometers were modified with insulated knife edges for the testing of the electrical resistance heated foil gauge specimens, and with special care being taken that the extensometers did not impose bending moments or axial loads to the test specimens in excess of 1% of the failing load. Total elongation was measured by the use of gauge marks on specimen surface.

A typical tensile test began by mounting a clean test specimen with appropriate holders and grips into the loading apparatus as shown in Figure 14. The specimen was then instrumented with extensometers (and thermocouples when the test was being run at other than ambient temperature). In the case of an elevated temperature test, the specimen was brought to testing temperature as quickly as possible; and after a 30 minute soak, the specimen was loaded at a strain rate of 0.005 in./in./min. up to yield. After yield strength the strain rate was increased to 0.04 in./in./min. or a strain rate to induce failure in one minute.

5.2 Compression Tests

The loading machines shown in Figures 15 and 16 have been described in paragraph 5.1 (Tensile Tests). In addition, care was taken to assure proper alignment and parallelism of the machine cross-heads.

The heat source for all elevated temperature compression tests was provided by a three-zone clam shell (Marshall) furnace, of 2200°F capability. The three zones could be independently adjusted to give the desired temperature gradient along the furnace axis. A Leeds-Northrup Control Recorder was used to respond to the signals generated by the three chromel-alumel thermocouples, that were intimate with the test specimen surface, producing continuous load versus deformation curves.

A temperature calibrating procedure was performed at each test temperature to determine optimum furnace control settings for the temperature. The resulting temperature gradient was ± 3°F for all test temperatures. A bar compression test specimen is shown in Figure 18.

Compression test specimens fabricated from sheet materials (0.040 inch and 0.080 inch thickness) were tested in a specially constructed fixture, see Figure 17, which provided lateral support to prevent buckling prior to yielding. In a series of calibration tests, the magnitude of frictional force that was transferred from lubricated specimen to specimen support guides was determined to be negligible. The bar specimens did not require lateral supports in testing, but because of the higher loads required to cause the material in these shapes to yield, the bar test fixtures were designed to accommodate loads up to 75,000 pounds, see Figure 16. The selection of the fixture material was critical due to range and repeated exposure to elevated temperatures. Rene′ 41 was chosen and it exhibited satisfactory properties throughout the test temperature range. Carbide inserts were used in the top and bottom subpress to resist deformation from concentrated compressive loads transmitted by test specimens.

Deformation measurements were made by means of a Baldwin-Lima-Hamilton Microformer Compressometer, calibrated and fitted with arm extensions to remove it from the elevated temperature environment of the furnace. This compressometer was connected to an autographic recorder to give load-deformation curves for each test.

A typical compression test began by recording the dimensions of a clean test specimen and then placing it into the test fixture. For sheet specimens, the specimen lateral support guides were positioned. Care was taken to assure axiality and alignment before application of load. The compressometer was then attached and the furnace closed. When the test temperature was stabilized, load was applied at 0.005 in./in./min. until yield is observed on a load deformation curve being autographically plotted.

5.3 Bearing Tests

The descriptions given of loading apparatus and heat source for the tension and compression tests are applicable for bearing tests. Bearing tests differ in respect to the type of fixtures employed, method and load application, and the manner in which the mechanical properties are determined. Clevis fixtures were used of various slot widths to accommodate each particular sheet specimen thickness. The application of

the load through clevis fixture to test specimen was by means of 0.250 inch diameter pin through reamed hole of specimen as shown in Figures 18, 19, and 20.

Measurement of bearing deformation was by means of a microformer extensometer with one set of arms attached to the loading clevis, and the other set attached through point contacts to the specimen edge on a line tangent to the loaded side and on the horizontal center line of bearing hole. The displacement detected by the extensometer was equivalent to the vertical deformation of the 0.250 inch diameter hole. The change in displacement sensed by the extensometer was fed into an autographic recorder which produced the load deformation plots.

The clevis fixtures were fabricated from Rene' 41 alloy material. The most severely stressed fixture component was the 0.250 inch diameter bearing pin, whose service life varied with test temperatures. Bearing pins of several materials were employed in the test program; the following table indicates the most effective material selection for each test temperature.

Bearing Pin Material

	Room	400°	600°	800°	1000°	1200°	1400°	1600°	1800°
Vascojet M-A	X	X	X	X	X				
Vascomax 300	X	X	X	X	X				
Rene' 41					X	X	X		
Haynes 713C								X	X

A bearing test specimen was prepared for tests by cleaning; hole dimensions and thickness measurements were noted. The specimen was placed in the clevis fixtures and secured in place with two pins. The specimen was then instrumented with thermocouple and extensometer, and then inserted into a clam-shell furnace. When both fixture and test specimen were stabilized at test temperature, the specimen was loaded at 0.02 in/in./min. and a load-deformation curve was obtained. After yield, the strain rate was increased to produce failure in less than a minute.

5.4 Shear Tests

Single shear tests were performed on sheet materials room and elevated temperatures, utilizing a heat source and axial loading apparatus described previously in paragraph 5.1. A clevis-pin fixture was used to attach the test specimens to self-aligning loading rods, as shown in Figure 21. Since the only value of interest was ultimate load, no extensometers were used.

Examination of test specimens after initial shear tests revealed the mode of failure to be other than true shear. The failures resulted from twisting of the test section perpendicular to the thickness dimension followed by tearing parallel to the slot, the latter action being accompanied by a lateral shift in the width direction, see Figure 22a.

The specimen configuration for sheet shear was chosen for this contract originally is recommended by ARTC-13 and elsewhere, and widely used throughout the industry. Ideally this specimen design should give a straight line shear failure

between the two 1/16 inch reamed holes which were 0.19 inches apart.

Test equipment was re-checked for alignment and axiality of load application, and found satisfactory. Additional test specimens were fabricated to incorporate changes in slot angles, i.e., 25°, 60° and 90°, as well as changes in shear height ratios. In other specimens, the 1/16 inch diameter holes were varied in position, some were placed on the center line, while others were made tangent to the center line.

When jigs were constructed to restrain the test section rotation, so that loading would be axial, the specimens failed by coining nuggets.

The problem of shear path instability was resolved satisfactorily by adjusting the distance between reamed holes. The distance between reamed holes for 0.020 inch thick sheet material was reduced to 0.070 inch and a subsequent w/h ratio of 9, and for the 0.040 and 0.080 inch thick sheet, the distance was made 0.100 inch for a w/h ratio of 6. (In this regard the thickness to shear path ratio seemed more critical than the w/h ratio). Consequently, the design of all single shear sheet specimens, for the four alloys tested, was changed in respect to hole distances.

The shear test fixture, see Figures 23 and 24, for double shear pin tests (pin specimens taken from bar and forgings) consisted of two clevis connected with a 1/4 inch center plate. A 1/2 inch diameter bolt was used for one clevis pin; the shear test specimen was the other clevis pin. Replaceable carbide inserts with 1/4 inch inside diameters were fitted to hold the specimen in the center plate and bottom clevis. These inserts prevented deformation of the fixture in the vicinity of load application to pin shear specimen. The inserts were replaced as soon as they became damaged or worn.

Both sheet and pin shear tests were performed with strict adherence to ASTM Standards specifications for heating and soaking time, as well as specimen temperature control. The shear path distance, and specimen thickness were measured for all sheet specimens; (pin diameter in the case of pin specimens) prior to test. Upon application of loads, sheet shear specimens failed along shear path, and pin specimens by the formation of two new planes perpendicular to pin specimen axis.

5.5 <u>Creep Tests</u>

Creep tests were performed using the simple beam loading type apparatus, as shown in Figure 25, having a maximum lever arm ratio of 20 to 1. Depending on the loading requirement, a 10 to 1 ratio or direct loading pan was used. To minimize variability of results in elevated temperature creep, care was taken to insure that misalignment between load application and longitudinal axis of test specimen was less than 1% of the working range. Eccentricity of loading is critical for creep tests, especially when small deformations (less than 1%) with time must be measured. Reproducibility of results also depends on rigid adherence to temperature measurement standards (as outlined by ASTM Standards), as well as the dependability of equipment and/or thermocouples to monitor these temperatures over periods of 1000 hours.

The electrical resistance furnaces used were specially constructed with an 18 inch long alundum tube wound with nichrome wire, with the upper and lower halves of main winding rheostat controlled. A pyrex "window" tube, covered at each end through which the creep measurements were made, contained rheostat controlled

windings, so that exceptionally fast temperature adjustments were possible. In addition, the furnace was designed with an inner "shielding tube" for the purpose of reducing hot spots. Indicated temperature deviations from nominal could be maintained at a maximum ± 2°F for each test duration. A diagram of furnace is shown in Figure 26.

Three chromel-alumel thermocouples were attached to test specimen gauge section, and test temperature was maintained by Minneapolis-Honeywell "Electronik" on/off controllers. Furnace control was through a centrally located thermocouple. All temperatures could be simultaneously printed on the same recorder chart when a temperature check was necessary. A minimum of three creep deformation readings were made daily during the first fifty hours of a test. More frequent readings, as many as ten per hour, were made when the nature of the creep curve warranted it. Instrumented test specimens are shown in Figures 27 and 28.

Extension measurements were made optically, using notched platinum wire-in-tube extensometers mounted on the shoulders of the test specimens. Two sets of the platinum wire-in-tube arrangement were mounted on each specimen, so that corresponding readings on two sides could be averaged to compensate for any unavoidable load eccentricity. The filar eyepiece microscopes used read directly to 0.00004 inches.

Prior to loading of test specimens, the furnaces were always brought to the desired temperature. The correct specimen temperature and gradient were achieved, and the specimen stabilized for 1/2 hour. Initial loadings were done in small increments well within the elastic range of test specimen previously determined. With the addition of each small increment, an elongation measurement was made. Readings of total elongation on loading could be made (after incremental loadings) so that the elastic contribution could be determined and subtracted.

5.6 Stress Rupture Tests

For the stress-rupture testing, the procedures and apparatus were generally the same as outlined for creep testing, except that the platinum wire-in-tube extensometers were not used. In this phase of the testing, we were concerned with time-to-rupture under a constant tensile load at a constant temperature.

Upon fracture of a specimen a timing device, actuated at the beginning of the test, would stop automatically to give test time duration. Another switch actuated by specimen fracture would stop the furnace power.

5.7 Fatigue Tests

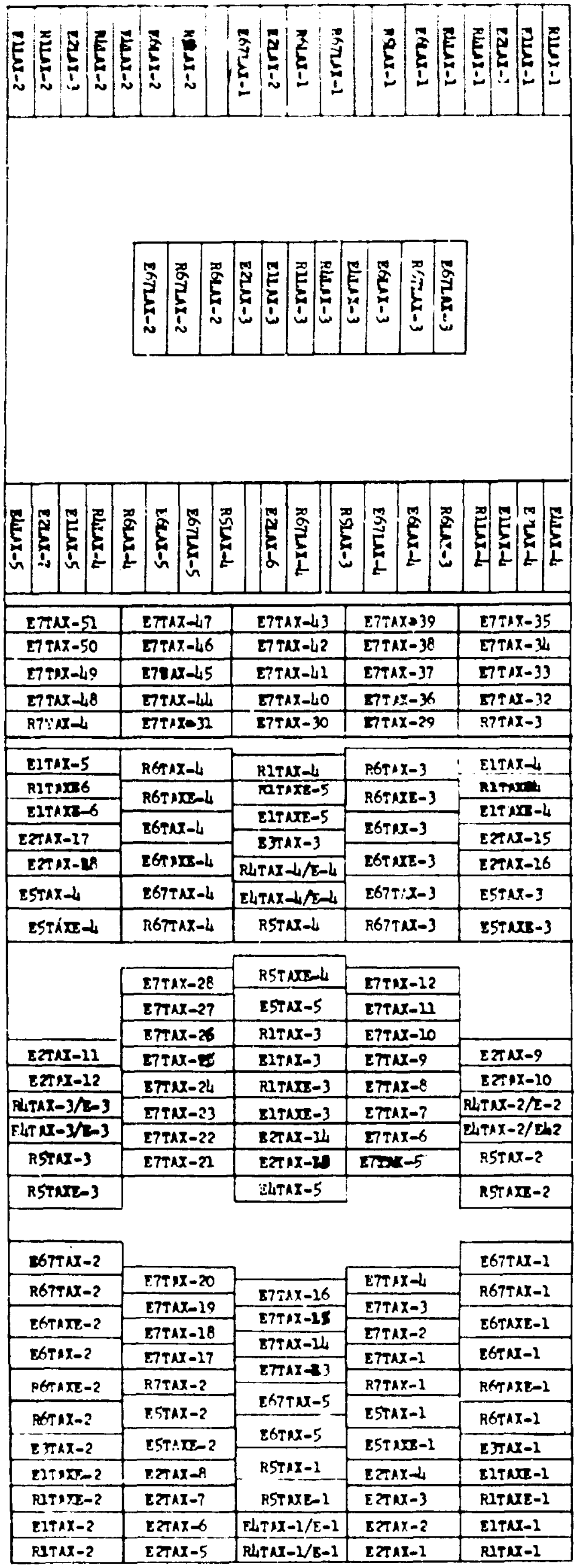
Several types of fatigue equipment were used to perform the axial tension-tension fatigue tests under this contract (see Figures 29 and 30). Selection of a test machine was on the basis of required stress-level, cycling rate, and stress-ratio. All 1800 CPM cycling speed fatigue tests were performed on Baldwin SF-10-U, SF-1-U, and IV-4F type machines. The machines were equipped with 5 to 1 multipliers. A Wiedemann-Baldwin SF-4 was used for testing in the 3600 CPM range. These machines were equipped with automatic pre-load maintainers. All dynamic systems of fatigue testing machines were checked to insure conformance to cycling speeds. Dynamic loading systems were checked and calibrated periodically.

Electrical resistance heating furnaces with 2200°F capability were used, as shown in Figure 31. Chromel-alumel thermocouples were calibrated at each test temperature against standards traceable to the National Bureau of Standards. Separate thermocouples were used for controlling and monitoring. On initial tests at each temperature, dummy specimens were instrumented with 4 thermocouples at each temperature. By utilizing Brown "Electronik", and/or Leeds-Northrup indicating controlling recorders, temperatures were controlled within ± 5°F to 1800°F. Care was taken to insure alignment of test specimens, as shown in Figure 32.

SECTION V - TEST PROCEDURES

5.8 Figures 1 through 32

FIG. 1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R6LAX-2
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E1LAX-3
R1LAX-3
R4LAX-3
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E6LAX-3
R67LAX-3
E67LAX-3
E7TAX-51
E7TAX-50
E7TAX-49
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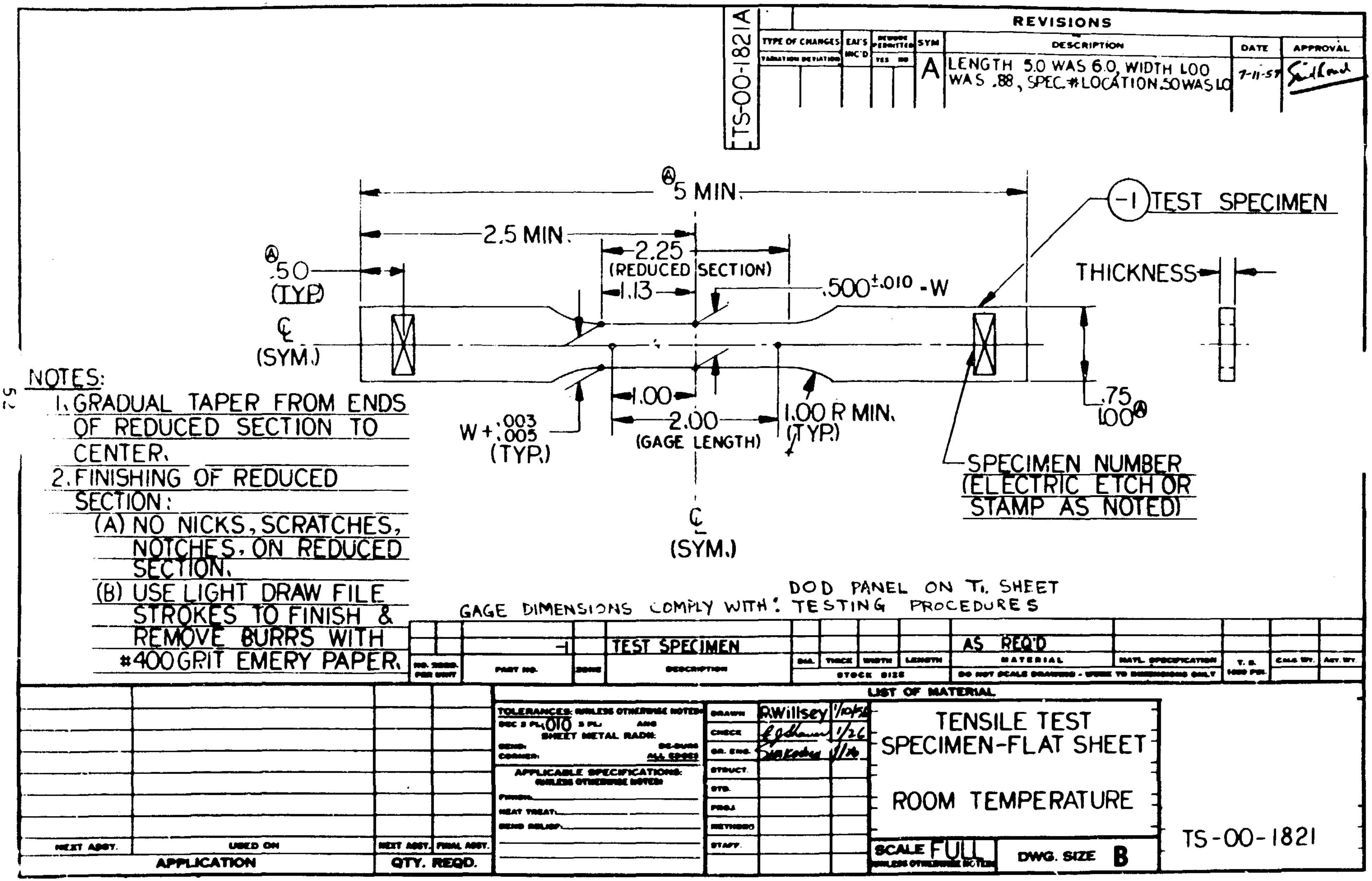
FIG. 2



TS-00-1821A
REVISIONS
TYPE OF CHANGES
VARIATION DEVIATION
EAI'S INC'D
SYM
DESCRIPTION
DATE
APPROVAL
A
LENGTH 5.0 WAS 6.0, WIDTH 1.00 WAS .88, SPEC.# LOCATION .50 WAS 1.0
7-11-57
5 MIN.
2.5 MIN.
2.25 (REDUCED SECTION)
1.13
.50 (TYP)
(SYM.)
.500±.010 -W
-1 TEST SPECIMEN
THICKNESS
1.00
2.00 (GAGE LENGTH)
W+.003 -.005 (TYP.)
1.00 R MIN. (TYP.)
.75 1.00
SPECIMEN NUMBER (ELECTRIC ETCH OR STAMP AS NOTED)
(SYM.)
NOTES:
1. GRADUAL TAPER FROM ENDS OF REDUCED SECTION TO CENTER.
2. FINISHING OF REDUCED SECTION:
(A) NO NICKS, SCRATCHES, NOTCHES, ON REDUCED SECTION.
(B) USE LIGHT DRAW FILE STROKES TO FINISH & REMOVE BURRS WITH #400 GRIT EMERY PAPER.
GAGE DIMENSIONS COMPLY WITH: DOD PANEL ON Ti. SHEET TESTING PROCEDURES
-1
TEST SPECIMEN
AS REQ'D
PART NO.
DESCRIPTION
STOCK SIZE
MATERIAL
LIST OF MATERIAL
TOLERANCES: UNLESS OTHERWISE NOTED
.010
SHEET METAL RADII
ALL CORNERS
APPLICABLE SPECIFICATIONS:
DRAWN RWillsey
CHECK
GR. ENG.
TENSILE TEST SPECIMEN-FLAT SHEET
ROOM TEMPERATURE
SCALE FULL
DWG. SIZE B
TS-00-1821
NEXT ASSY.
USED ON
APPLICATION
QTY. REQD.

FIG. 3

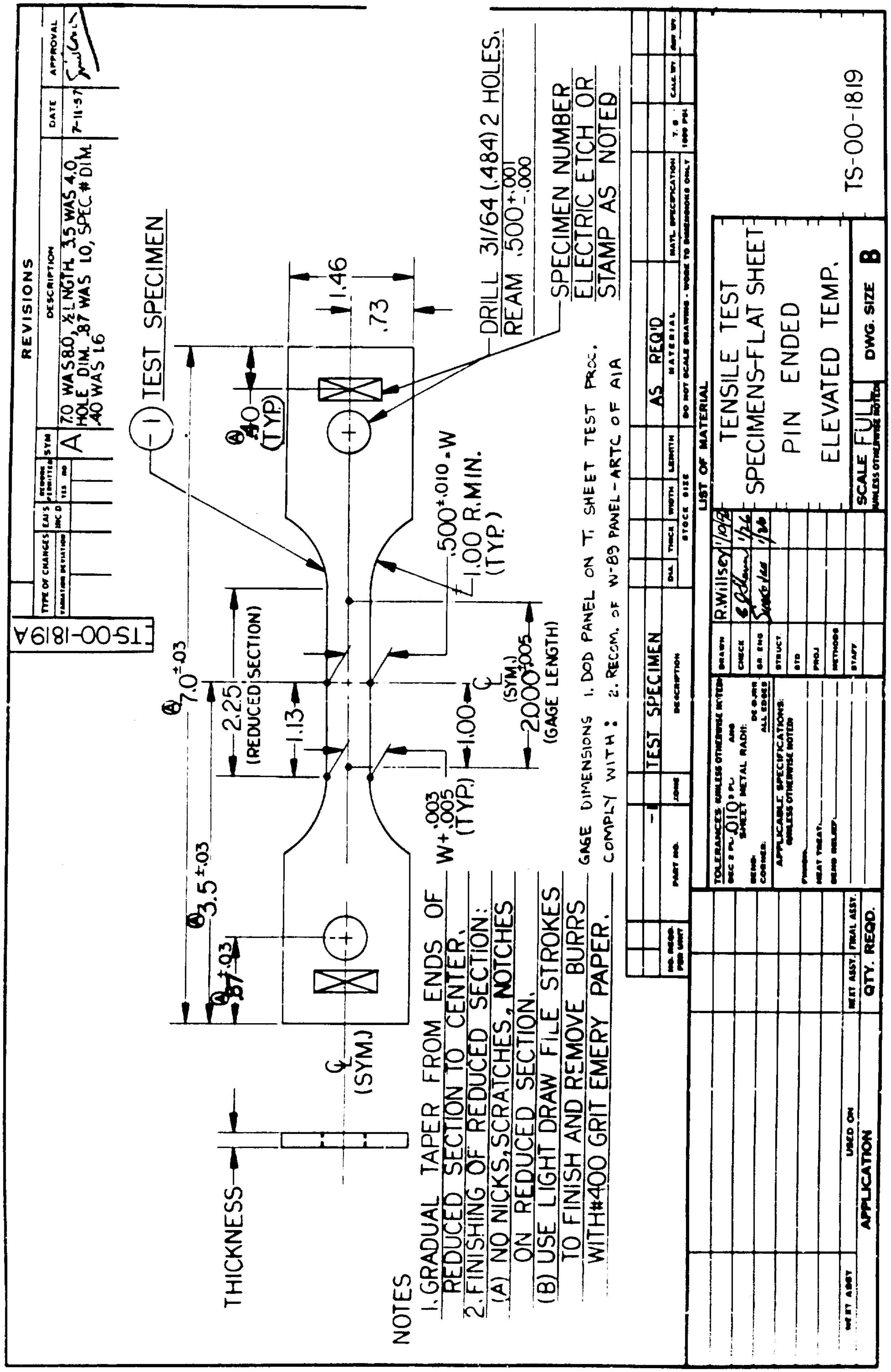
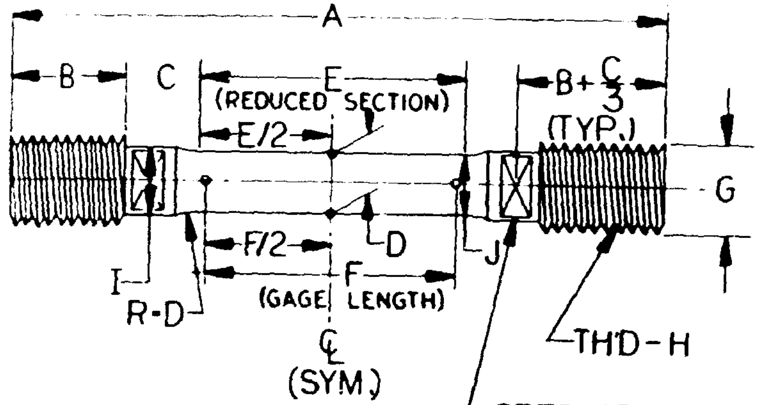

REVISIONS
A 7.0 WAS 8.0, ⌀ LNGTH 3.5 WAS 4.0, HOLE DIM. .87 WAS 1.0, SPEC # DIM. .40 WAS 1.6 7-11-57
TS-00-1819A
(1) TEST SPECIMEN
1.46
.73
DRILL 31/64 (.484) 2 HOLES, REAM .500 +.001 -.000
SPECIMEN NUMBER ELECTRIC ETCH OR STAMP AS NOTED
.40 (TYP)
.500 ±.010 = W
1.00 R. MIN. (TYP.)
7.0 ±.03
2.25 (REDUCED SECTION)
1.13
1.00
℄ (SYM.)
2.000 ±.005 (GAGE LENGTH)
3.5 ±.03
.87 ±.03
W + .003 .005 (TYP.)
℄ (SYM.)
THICKNESS
NOTES
1. GRADUAL TAPER FROM ENDS OF REDUCED SECTION TO CENTER.
2. FINISHING OF REDUCED SECTION:
(A) NO NICKS, SCRATCHES, NOTCHES ON REDUCED SECTION.
(B) USE LIGHT DRAW FILE STROKES TO FINISH AND REMOVE BURRS WITH #400 GRIT EMERY PAPER.
GAGE DIMENSIONS 1. DOD PANEL ON Ti SHEET TEST PROC.
COMPLY WITH: 2. RECOM. OF W-89 PANEL - ARTC OF AIA
TEST SPECIMEN
AS REQ'D
LIST OF MATERIAL
R. Willsey
TENSILE TEST SPECIMENS-FLAT SHEET PIN ENDED ELEVATED TEMP.
SCALE FULL
DWG. SIZE B
TS-00-1819
APPLICATION
QTY. REQD.

FIG. 4

REVISIONS

TS-00-1817A	TYPE OF CHANGES (VARIATION / DEVIATION)	EAI'S INC'D	REDOES PERMITTED (YES / NO)	SYM	DESCRIPTION	DATE	APPROVED
				A	COL. D .505 WAS .500, .252 WAS .250, COL. I DEC. NO'S WERE FRACTIONS	7/12/57	



SPECIMEN NUMBER (ELECTRIC ETCH OR STAMP AS NOTED.)

DASH NO.	A IN.	B IN.	C IN.	D IN.	E IN.	F IN.	G IN.	H IN.	I ±.005 IN.	J IN.
-1	5 1/2	1	5/8	.505 ±.005	2 1/4	2.000 ±.005	3/4	3/4-10	.620	D +.005 +.003
-3	5	7/8	5/8	.438 ±.004	2	1.750 ±.005	5/8	5/8-11	.500	D +.004 +.002
-5	4 1/4	3/4	1/2	.375 ±.003	1 3/4	1.500 ±.005	9/16	9/16-12	.453	D +.004 +.002
-7	3 3/4	5/8	1/2	.313 ±.002	1 1/2	1.250 ±.005	1/2	1/2-13	.390	D +.003 +.001
-9	3	1/2	3/8	.252 ±.001	1 1/4	1.000 ±.005	7/16	7/16-14	.343	D +.002 +.001
-11	2 3/4	1/2	3/8	.188 ±.001	1	.750 ±.005	3/8	3/8-16	.281	D +.002 +.0005
-13	2 1/8	3/8	5/16	.125 ±.001	3/4	.500 ±.005	1/4	1/4-20	.187	D +.001 +.0005

NOTES:

1. GRADUAL TAPER FROM ENDS OF REDUCED SECTION TO CENTER.
2. FINISHING OF REDUCED SECTION:
   (a) NO NICKS, SCRATCHES, NOTCHES, IN REDUCED SECTION.
   (b) POLISH WITH #400 GRIT EMERY PAPER.
3. TOLERANCE ON ALL FRACTIONAL DIMENSIONS ±1/16
4. USE -1 & 9 FOR HIGH TEMP. TEST. CREEP TEST & STRESS RUPTURE SPECIMENS SHOULD BE MADE WITH J=D. THESE COMPLY WITH RECOMENDATION OF W-89 PANEL - ARTC OF AIA

NO. REQD PER UNIT	PART NO.	ZONE	DESCRIPTION	DIA.	THICK	WIDTH	LENGTH	MATERIAL	MAT'L SPECIFICATION	T. S. 1000 PSI	CALC. WT.	ACT. WT.
				STOCK SIZE				DO NOT SCALE DRAWING - WORK TO DIMENSIONS ONLY				

LIST OF MATERIAL

NEXT ASSY.	USED ON	NEXT ASSY.	FINAL ASSY.
APPLICATION		QTY. REQD.	

TOLERANCES: UNLESS OTHERWISE NOTED
DEC. 2 PL: .010 3 PL: ANG
SHEET METAL RADII:
BEND:
CORNER:
DE-BURR ALL EDGES

APPLICABLE SPECIFICATIONS: UNLESS OTHERWISE NOTED
FINISH:
HEAT TREAT:
BEND RELIEF:

DRAWN	R.Willsey	1/10/56
CHECK	[illegible]	1/26
GR. ENG.	Sintaka	1/26
STRUCT		
STD.		
PROJ.		
METHODS		
STAFF		

TENSILE, CREEP & STRESS RUPTURE ROUND BAR SPECIMENS

SCALE NONE UNLESS OTHERWISE NOTED | DWG. SIZE B

TS-00-1817

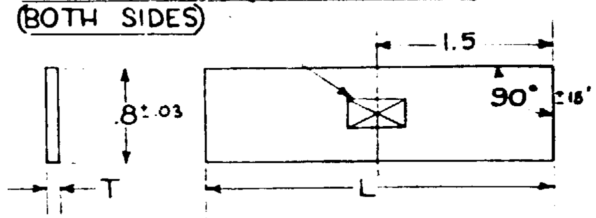
FIG. 5

TS-00-1916

REVISIONS

TYPE OF CHANGES (VARIATION / DEVIATION)	EA'S INC D	REWORK PERMITTED (YES / NO)	SYM	DESCRIPTION	DATE	APPROVAL

SPECIMEN NUMBER TO BE PUT ON IN INK. (DO NOT STAMP) (BOTH SIDES)



DASH NO.	T IN.	L (±.005) IN.
-1	<.035	2.945
-2	.036-.090	3.000
-3	>.090	3.010

NOTES:
1. ENDS MUST BE FLAT AND PARALLEL TO WITHIN .0005"
2. REMOVE BURRS FROM EDGES WITH NO. 400 GRIT EMERY PAPER. DO NOT BREAK CORNERS.
3. SURFACE TO BE FREE FROM NICKS AND SCRATCHES.

NO. REQD. PER UNIT	PART NO.	ZONE	DESCRIPTION	DIA.	THICK	WIDTH	LENGTH	MATERIAL	MATL. SPECIFICATION	T. S. 1000 PSI	CALC. WT.	ACT. WT.
				STOCK SIZE				DO NOT SCALE DRAWING - WORK TO DIMENSIONS ONLY				

LIST OF MATERIAL

TOLERANCES (UNLESS OTHERWISE NOTED)
DEC 2 PL. 3 PL. ANG.
SHEET METAL RADII:
BEND- CORNER- DE-BURR ALL EDGES
APPLICABLE SPECIFICATIONS (UNLESS OTHERWISE NOTED)
FINISH
HEAT TREAT
BEND RELIEF

DRAWN — 8-56
CHECK — 10/1/56
GR. ENG. — 4/1/57
STRUCT
STD
PROJ
METHODS
STAFF

COMPRESSION SPECIMEN - SHEET MATERIAL ROOM & ELEV. TEMP.

SCALE NONE. UNLESS OTHERWISE NOTED
DWG. SIZE B
TS-00-1916

NEXT ASSY. | USED ON | NEXT ASSY. | FINAL ASSY.
APPLICATION | QTY. REQD.

6-1-56 REV. 7-56 DEFIANCE 1000H

FIG. 6

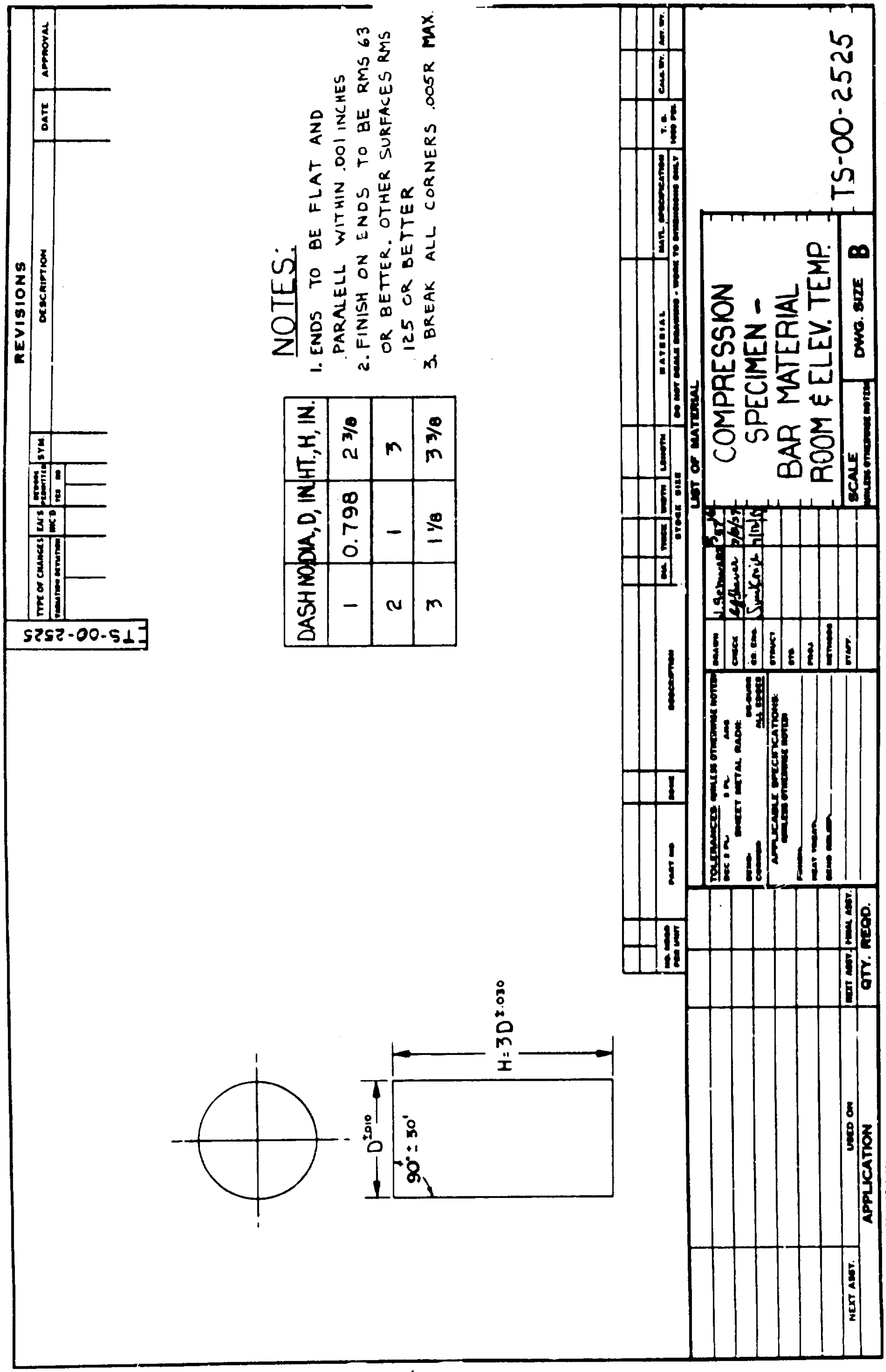
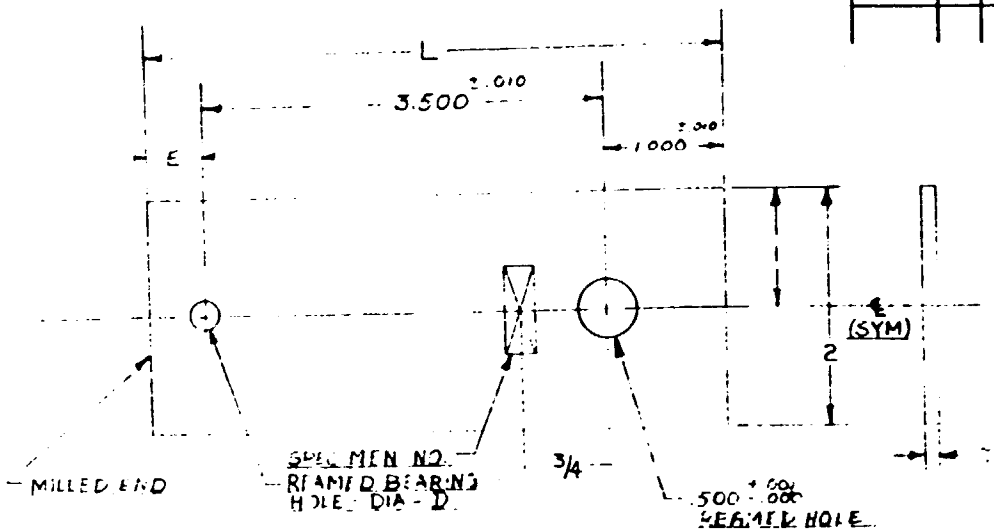

REVISIONS
TYPE OF CHANGES
DESCRIPTION
DATE
APPROVAL
TS-00-2525
NOTES:
1. ENDS TO BE FLAT AND PARALELL WITHIN .001 INCHES
2. FINISH ON ENDS TO BE RMS 63 OR BETTER, OTHER SURFACES RMS 125 OR BETTER
3. BREAK ALL CORNERS .005R MAX.
DASH NO. | DIA., D, IN. | HT., H, IN.
1 | 0.798 | 2 3/8
2 | 1 | 3
3 | 1 1/8 | 3 3/8
H=3D ±.030
D ±.010
90° ± 30'
LIST OF MATERIAL
MATERIAL
STOCK SIZE
TOLERANCES
APPLICABLE SPECIFICATIONS
COMPRESSION SPECIMEN - BAR MATERIAL ROOM & ELEV. TEMP.
SCALE
DWG. SIZE B
TS-00-2525
QTY. REQD.
APPLICATION
USED ON
NEXT ASSY.

FIG. 7



NO	L ±.010	D +.001 -.000	W ±.015 (REF)	E	E/D (REF)	T (REF)
1	4.875	.250	2.00	.375 ±.005	1.5	.020, .040, .080
2	5.000	.250	2.00	.500 ±.005	2.0	.020, .040, .080
3	5.063	.375	2.00	.563 ±.005	1.5	.375
4	5.250	.375	2.00	.750 ±.010	2.0	.375

NOTES -

1 FINISH CRITICAL ON MILLED END ONLY - 125 RMS MAX
2 BOTH HOLES TO BE IN LINE AND ON ℄ (±.001)

REVISIONS						
TYPE OF CHANGE	EAI INC	REWORK PERMIT YES / NO	SYM	DESCRIPTION	DATE	APPROVED

LIST OF MATERIAL

QTY REQD	SYM	VENDOR DATA PER	CODE IDENT	PART OR IDENTIFYING NO.	ZONE	NOMENCLATURE OR DESCRIPTION	STOCK SIZE DIA	THICK	WIDTH	LENGTH	MATERIAL	MATL SPECIFICATION	TS 1000 PSI	UNIT WT

NEXT ASSEMBLY	USED ON	NEXT ASSY	FINAL ASSY
APPLICATION		QUANTITY REQD	

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED

DEC TOL	SH MET. RAD
2 PLACE ± .010	BEND:
3 PLACE ± .	COR:
ANGULAR ±	DEBURR ALL EDGES

APPLICABLE SPECIFICATIONS

FINISH:

HEAT TREAT:

BEND RELIEF:

FOR ADDL SPEC SEE NOTE

CONTRACT NO.

DRAWN	F.O. ESR	5-2-62
CHECKED	A. Kinne	Dec. 5, 1962
GR ENGR		
STRUCT		
STANDARD		
PROJ ENGR		
WEIGHTS		
SPARES		

DO NOT SCALE DRAWING

BEARING SPECIMENS

ROOM AND ELEVATED TEMPERATURE

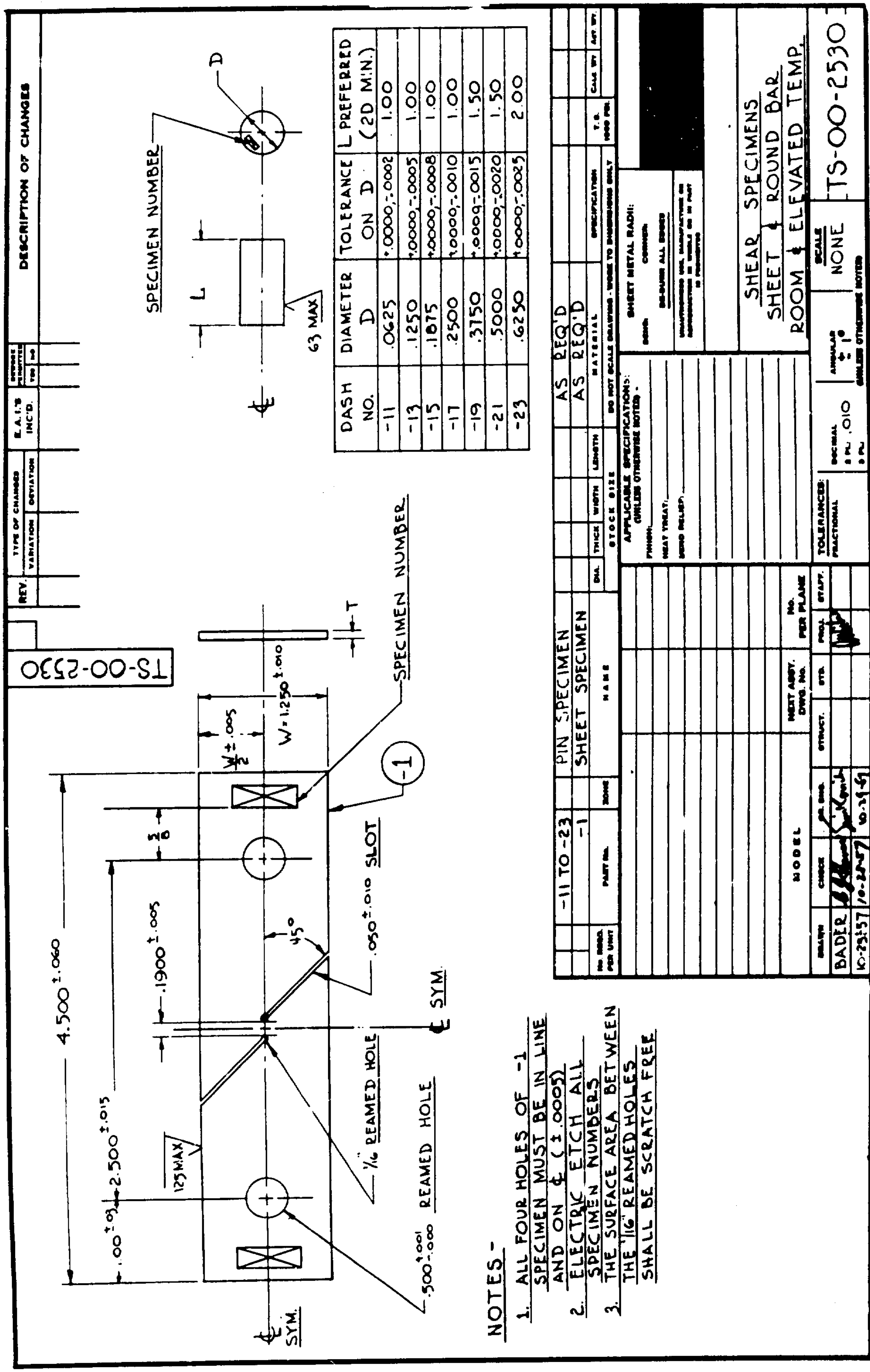
SHORT TIME AND CREEP TESTS

CODE IDENT NO.	SIZE	
77751	B	TS-00-2529 B

SCALE FULL UNLESS OTHERWISE NOTED SHEET

HAC FORM NO E-1-38 REV. B

FIG. 8



DASH NO.	DIAMETER D	TOLERANCE ON D	L PREFERRED (2D MIN.)
-11	.0625	+.0000,-.0002	1.00
-13	.1250	+.0000,-.0005	1.00
-15	.1875	+.0000,-.0008	1.00
-17	.2500	+.0000,-.0010	1.00
-19	.3750	+.0000,-.0015	1.50
-21	.5000	+.0000,-.0020	1.50
-23	.6250	+.0000,-.0025	2.00

FIG. 9

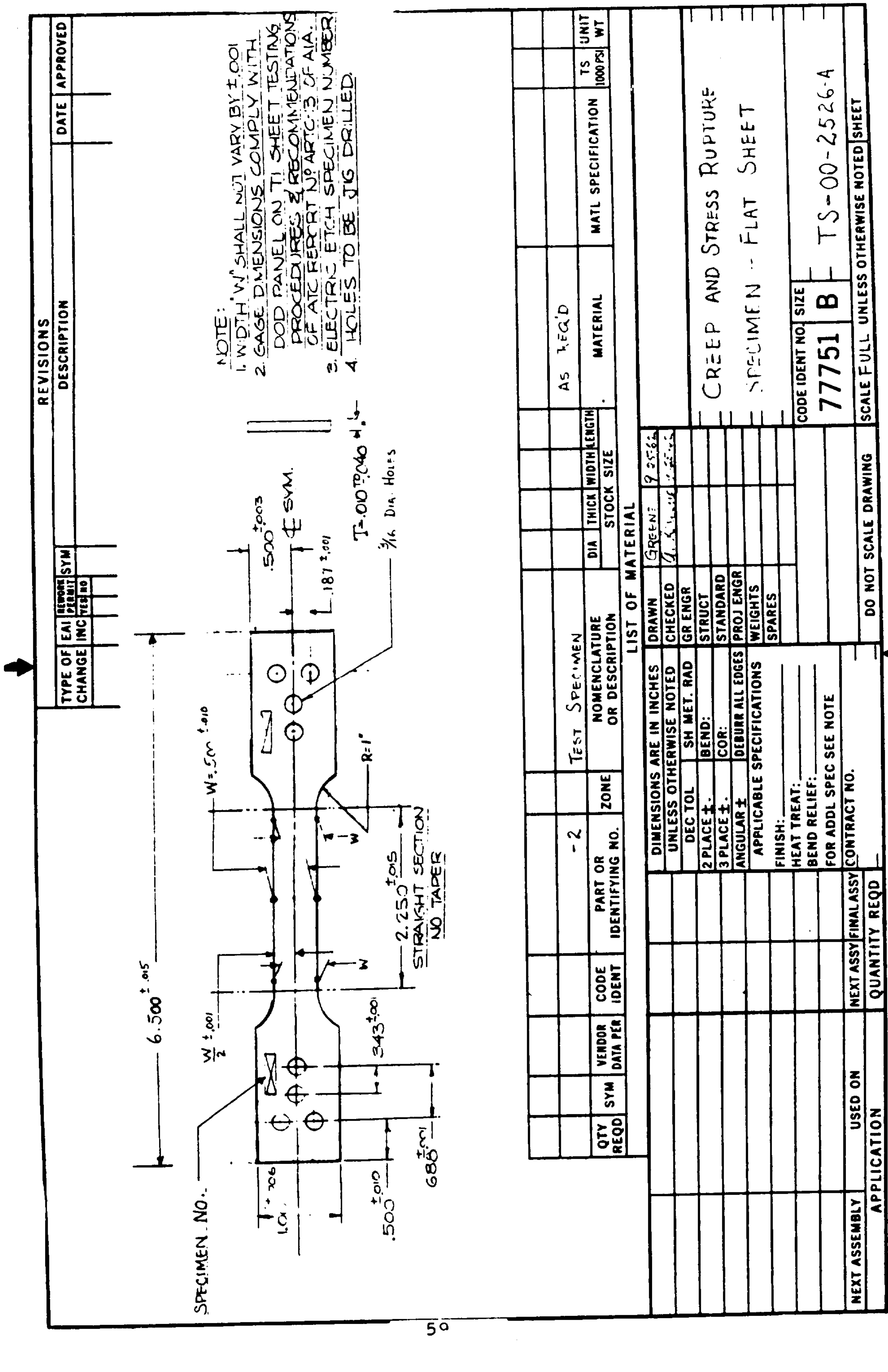
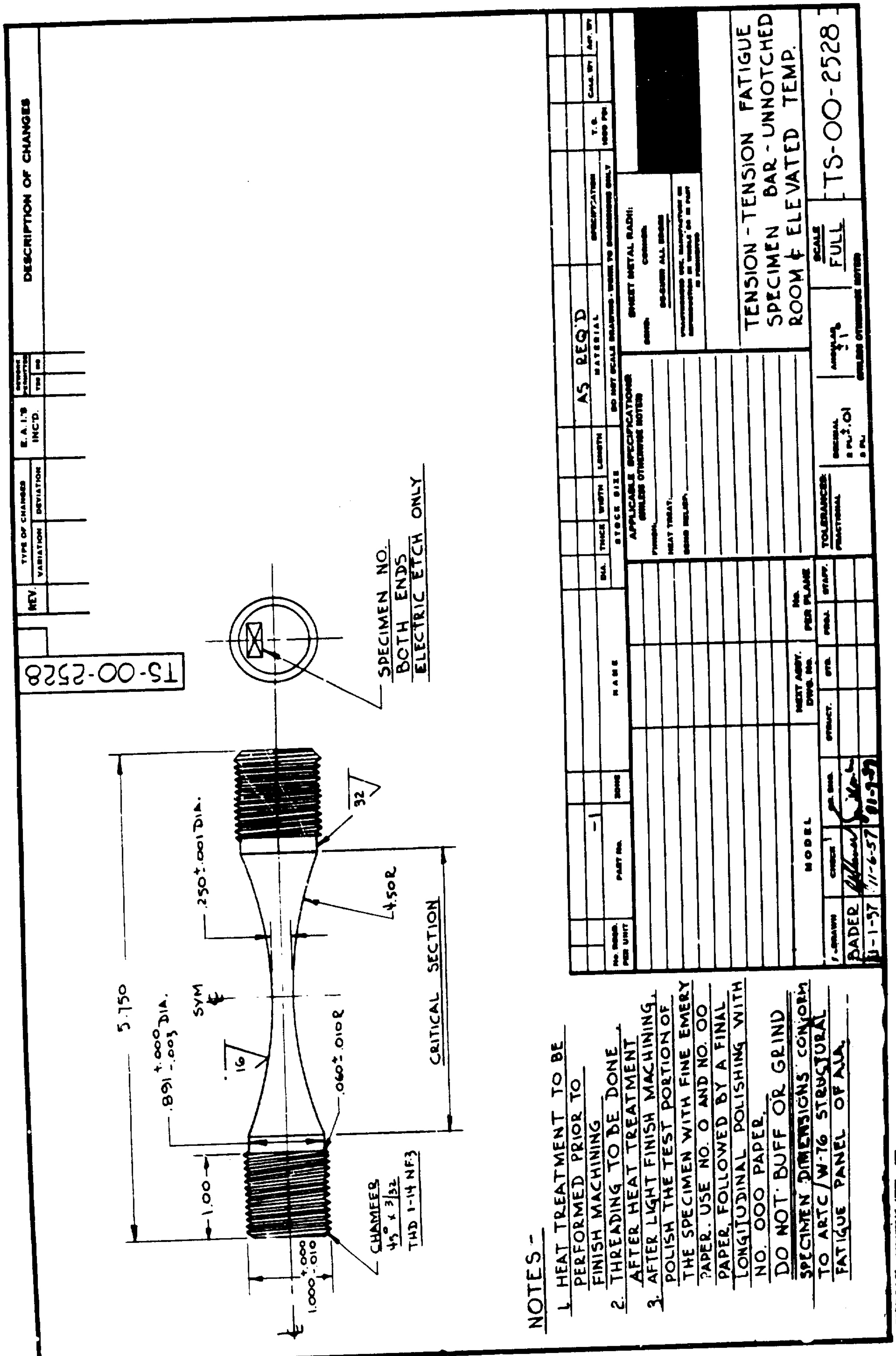
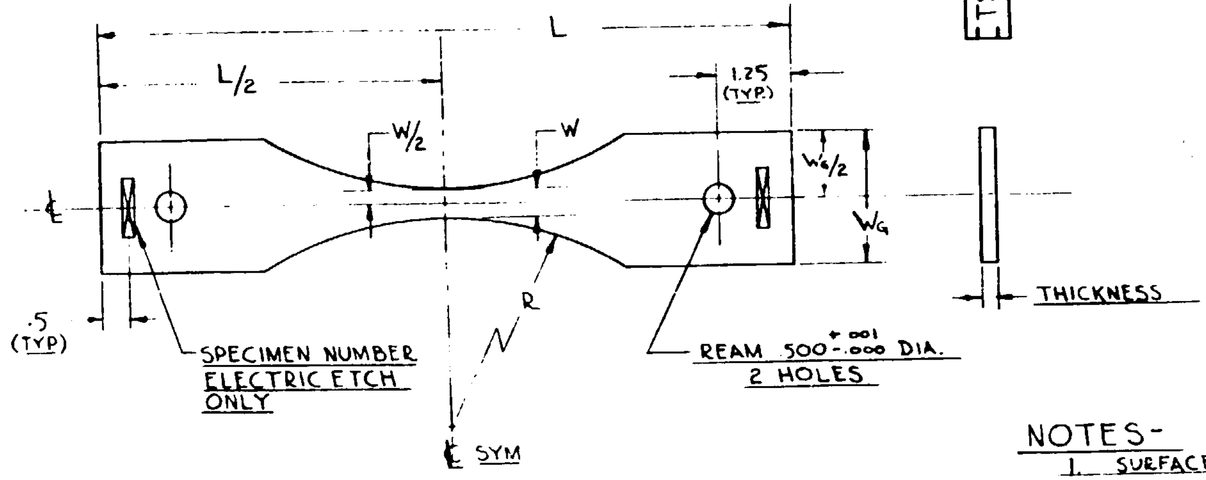

REVISIONS
TYPE OF CHANGE
EAI INC
REWORK PERMIT YES NO
SYM
DESCRIPTION
DATE
APPROVED
NOTE:
1. WIDTH "W" SHALL NOT VARY BY ±.001
2. GAGE DIMENSIONS COMPLY WITH DOD PANEL ON TI SHEET TESTING PROCEDURES & RECOMMENDATIONS OF ATC REPORT No ARTC-3 OF AIA.
3. ELECTRIC ETCH SPECIMEN NUMBER
4. HOLES TO BE JIG DRILLED.
SPECIMEN NO.
6.500 ±.015
W/2 ±.001
W=.5 in ±.010
2.250 ±.015
STRAIGHT SECTION
NO TAPER
R=1"
.500 ±.003
℄ SYM.
.187 ±.001
.343 ±.001
.688 ±.001
.500 ±.010
T=.010 TO .040
3/16 DIA. HOLES
QTY REQD
SYM
VENDOR DATA PER
CODE IDENT
PART OR IDENTIFYING NO.
-2
ZONE
NOMENCLATURE OR DESCRIPTION
TEST SPECIMEN
DIA
THICK
WIDTH
LENGTH
STOCK SIZE
MATERIAL
AS REQ'D
MATL SPECIFICATION
TS 1000 PSI
UNIT WT
LIST OF MATERIAL
DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED
DEC TOL
SH MET. RAD
2 PLACE ±
BEND:
3 PLACE ±
COR:
ANGULAR ±
DEBURR ALL EDGES
APPLICABLE SPECIFICATIONS
FINISH:
HEAT TREAT:
BEND RELIEF:
FOR ADDL SPEC SEE NOTE
CONTRACT NO.
DRAWN
GREENE
CHECKED
GR ENGR
STRUCT
STANDARD
PROJ ENGR
WEIGHTS
SPARES
CREEP AND STRESS RUPTURE
SPECIMEN - FLAT SHEET
CODE IDENT NO.
77751
SIZE
B
TS-00-2526-A
SCALE FULL UNLESS OTHERWISE NOTED
SHEET
DO NOT SCALE DRAWING
NEXT ASSY
FINAL ASSY
QUANTITY REQD
NEXT ASSEMBLY
USED ON
APPLICATION

FIG. 10



TS-00-2528
REV.
TYPE OF CHANGES
VARIATION
DEVIATION
E.A.I.'S INC'D.
DESCRIPTION OF CHANGES
5.750
1.00
.891 +.000 -.003 DIA.
SYM
16
.060±.010R
.250±.001DIA.
4.50R
32
CRITICAL SECTION
1.000 +.000 -.010
CHAMFER 45° x 3/32
THD 1-14 NF3
SPECIMEN NO.
BOTH ENDS
ELECTRIC ETCH ONLY
NOTES -
1. HEAT TREATMENT TO BE PERFORMED PRIOR TO FINISH MACHINING
2. THREADING TO BE DONE AFTER HEAT TREATMENT
3. AFTER LIGHT FINISH MACHINING POLISH THE TEST PORTION OF THE SPECIMEN WITH FINE EMERY PAPER. USE NO. 0 AND NO. 00 PAPER, FOLLOWED BY A FINAL LONGITUDINAL POLISHING WITH NO. 000 PAPER.
DO NOT BUFF OR GRIND
SPECIMEN DIMENSIONS CONFORM TO ARTC/W-76 STRUCTURAL FATIGUE PANEL OF AIA.
AS REQ'D
MATERIAL
STOCK SIZE
APPLICABLE SPECIFICATIONS
SCALE
FULL
TENSION - TENSION FATIGUE SPECIMEN BAR - UNNOTCHED ROOM & ELEVATED TEMP.
TS-00-2528
BADER
11-1-57
11-6-57

FIG. 11



TS-00-2527

REVISIONS						
TYPE OF CHANGES (VARIATION / DEVIATION)	EA'S INC'D	REDESIGN PERMITTED (YES / NO)	SYM	DESCRIPTION	DATE	APPROVAL

NOTES-

1. SURFACE TO BE FREE OF NICKS SCRATCHES & NOTCHES
2. USE LIGHT FINISH MACHINING
3. POLISH SIDES OF SPECIMEN TEST SECTION LONGITUDINALLY USING NO. 0 THRU NO. 000 GRADE EMERY PAPER DO NOT BUFF
4. REMOVE ALL BURRS AND BREAK SHARP EDGES .005 R MAX.
5. HEAT TREATMENT TO BE PERFORMED PRIOR TO FINAL HAND FINISHING
6. HOLES TO BE ON ℄ (±.001)

DASH NO.	WIDTH W_g (±.010)	LENGTH L (±.05)	MINIMUM WIDTH W (±.005)	RADIUS R (±.01)
-1	2.250	12.00	.500	6.00
-3	1.500	7.50	.250	3.00

REDUCED AREA DIMENSIONS CONFORM TO ARTC/W-76 STRUCTURAL FATIGUE PANEL RECOMMENDATIONS OF AIA.

NO. REQD. PER UNIT	PART NO.	ZONE	DESCRIPTION	DIA.	THICK	WIDTH	LENGTH	MATERIAL	MATL. SPECIFICATION	T. S. 1000 PSI	CALC. WT.	ACT. WT.
	-1 & -3							AS REQ'D				

STOCK SIZE — DO NOT SCALE DRAWING - WORK TO DIMENSIONS ONLY

LIST OF MATERIAL

TOLERANCES: (UNLESS OTHERWISE NOTED) DEC 2 PL ±.01 3 PL ANG SHEET METAL RADII: BEND: CORNER: DE-BURR ALL EDGES

APPLICABLE SPECIFICATIONS: (UNLESS OTHERWISE NOTED) FINISH: HEAT TREAT: BEND RELIEF:

DRAWN	BADER	11/5/57
CHECK	[signature]	11/6/57
GR. ENG.	[signature]	11/7/57
STRUCT.		
STD.		
PROJ.		
METHODS		
STAFF.		

TENSION-TENSION FATIGUE SPECIMENS SHEET MATERIALS UNNOTCHED

SCALE HALF (UNLESS OTHERWISE NOTED) — DWG. SIZE B

TS-00-2527

NEXT ASSY.	USED ON	NEXT ASSY.	FINAL ASSY.
APPLICATION		QTY. REQD.	

S-1-50 REV. 7-60 DEFIANCE 1000H

FIG. 12

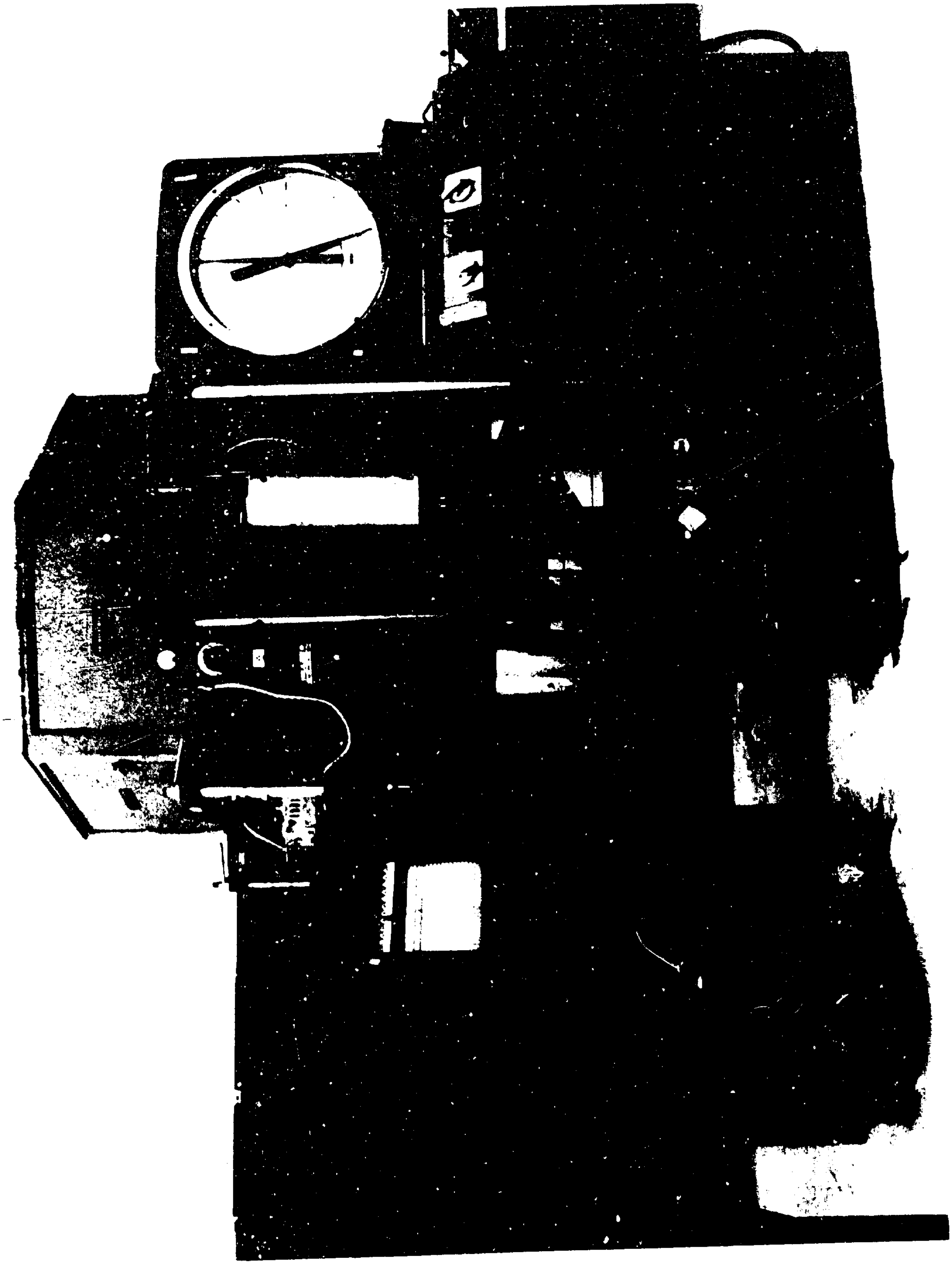


FIG. 13

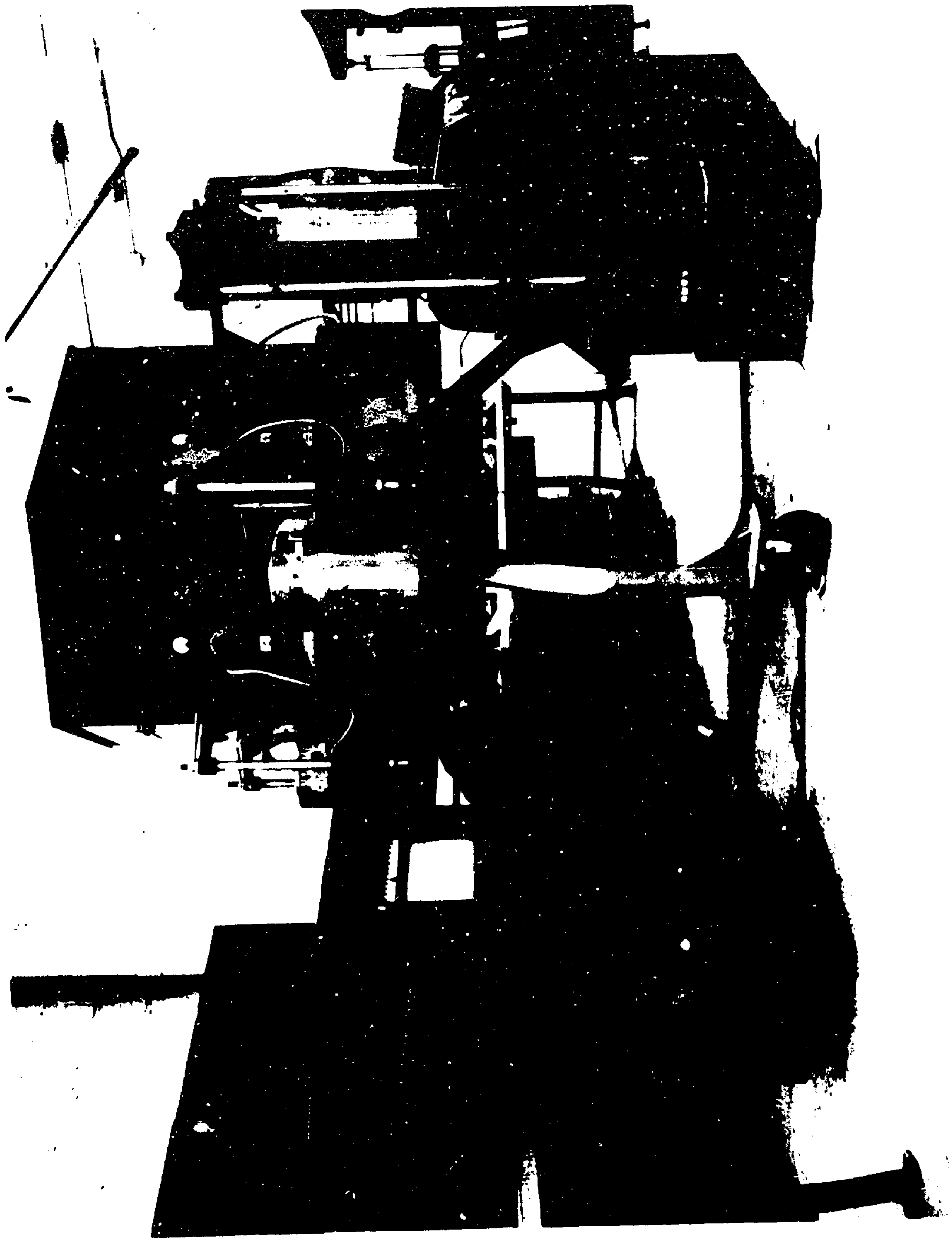


FIG. 14

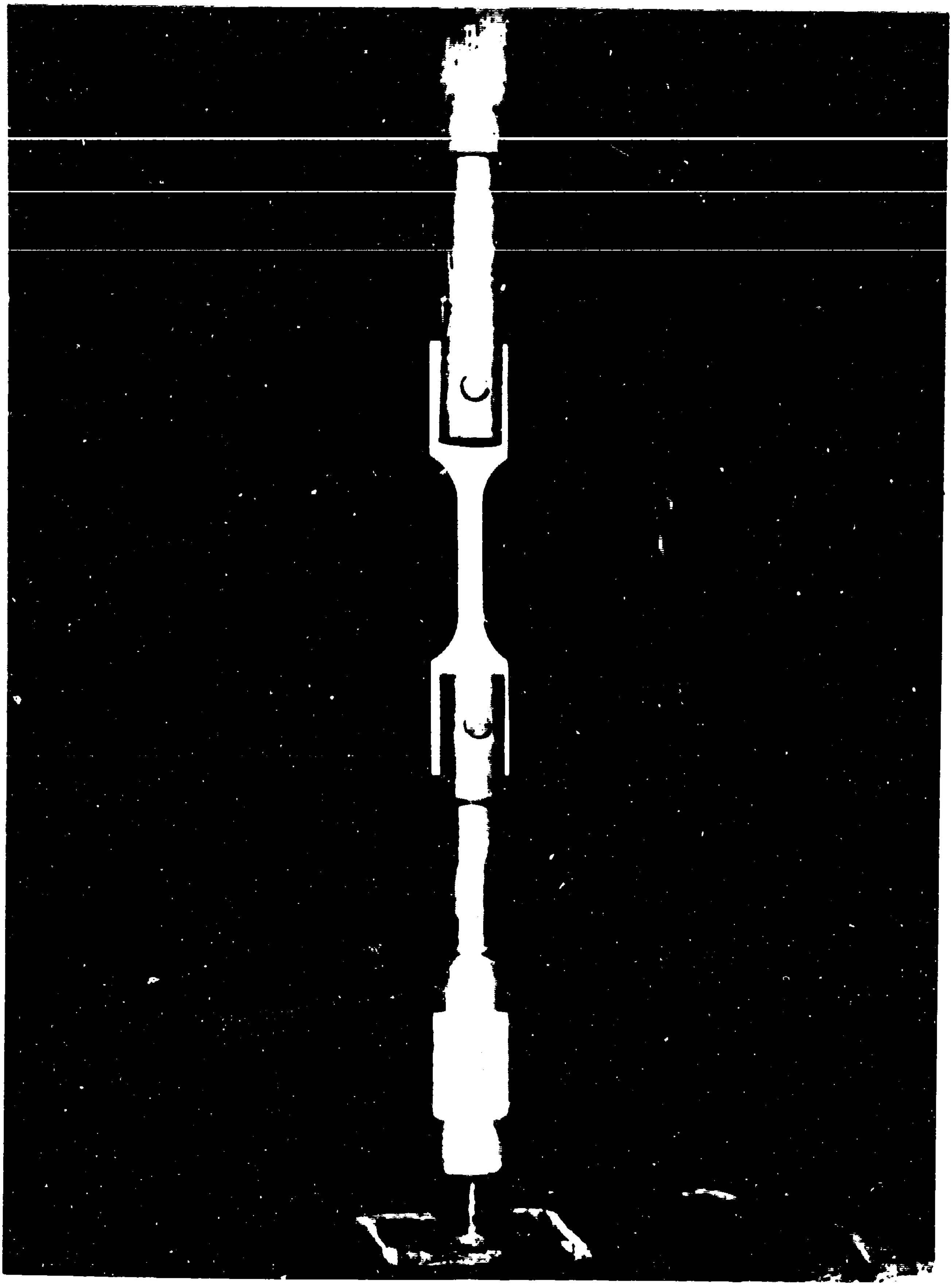


FIG. 15

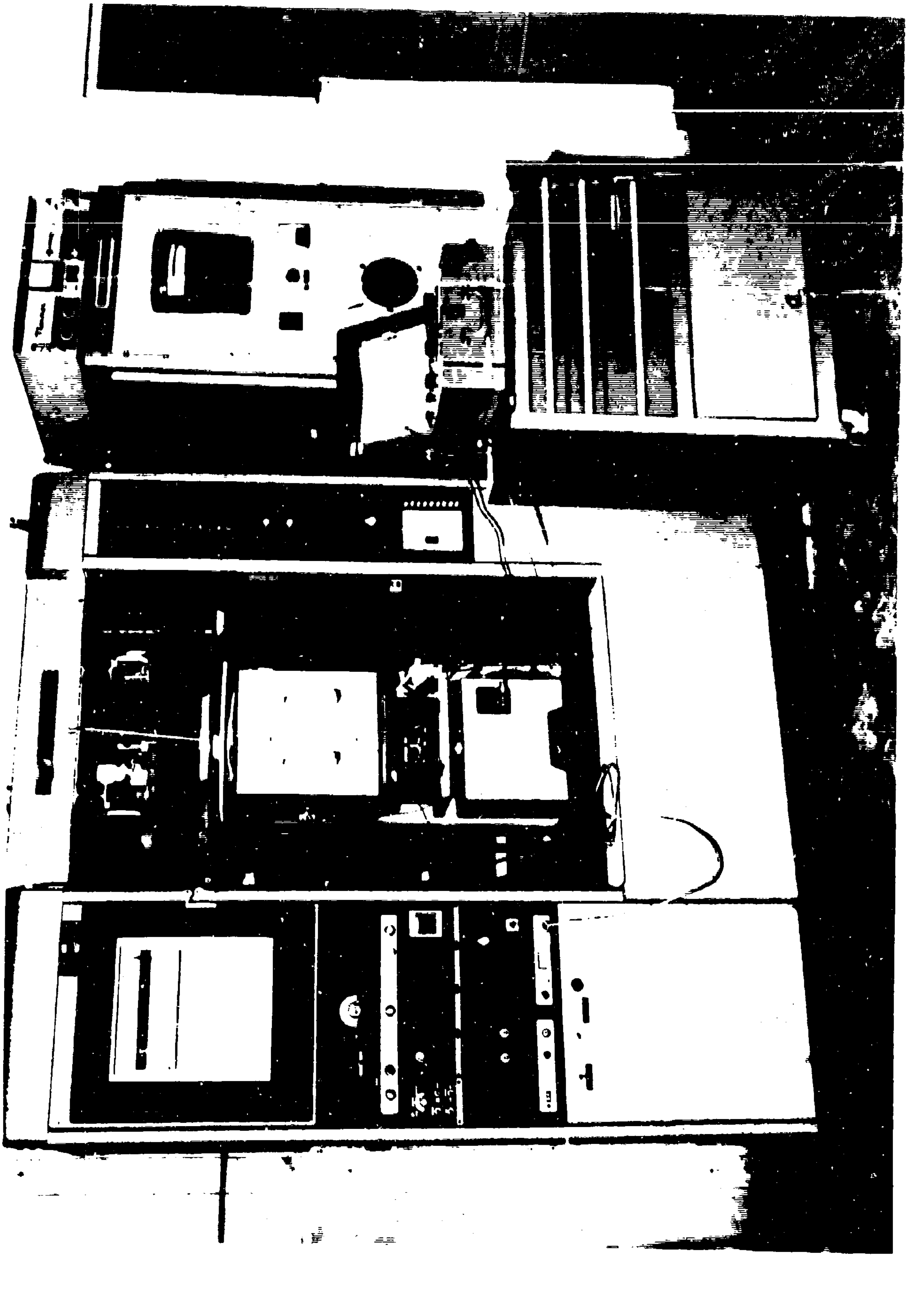


FIG. 16

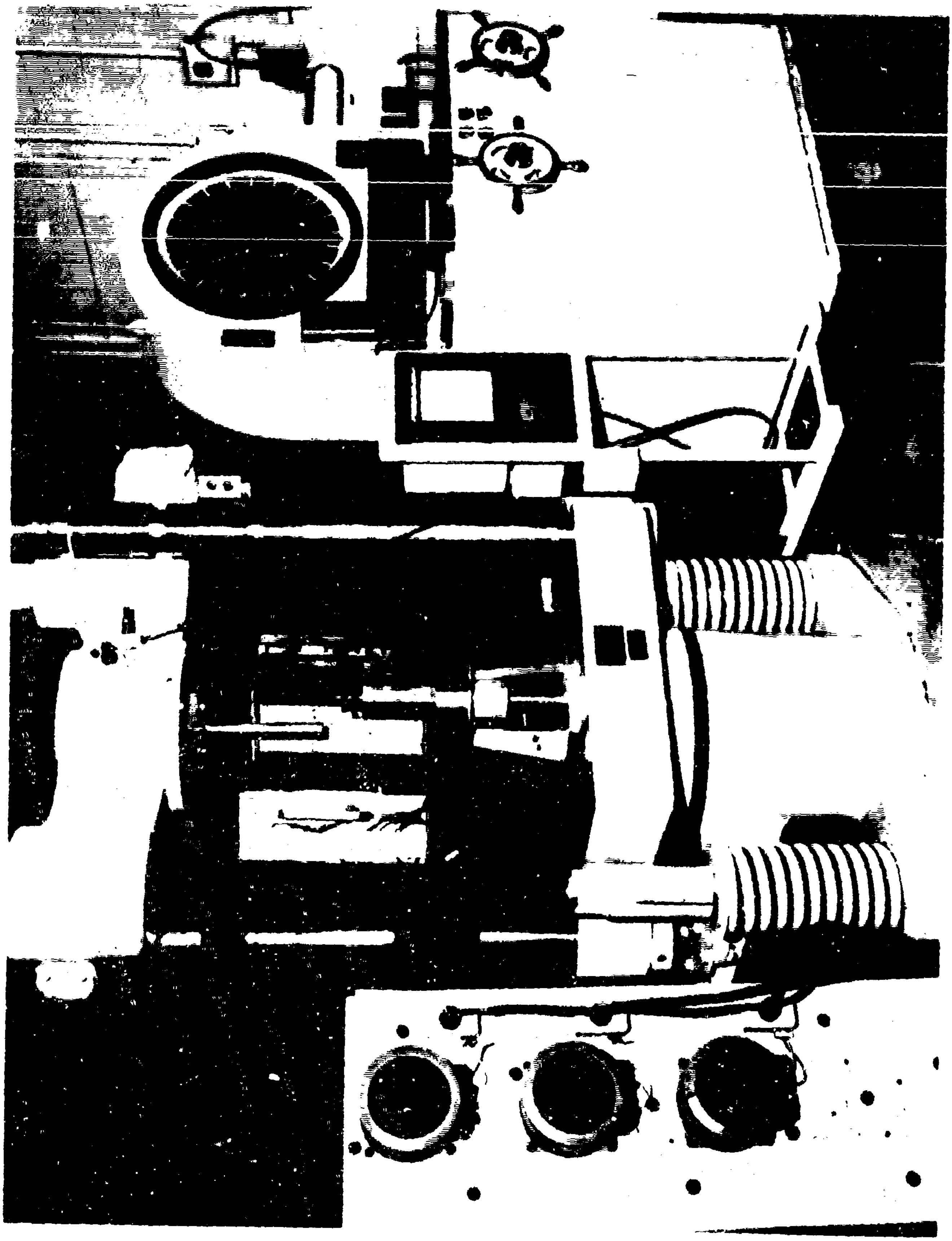


FIG. 17

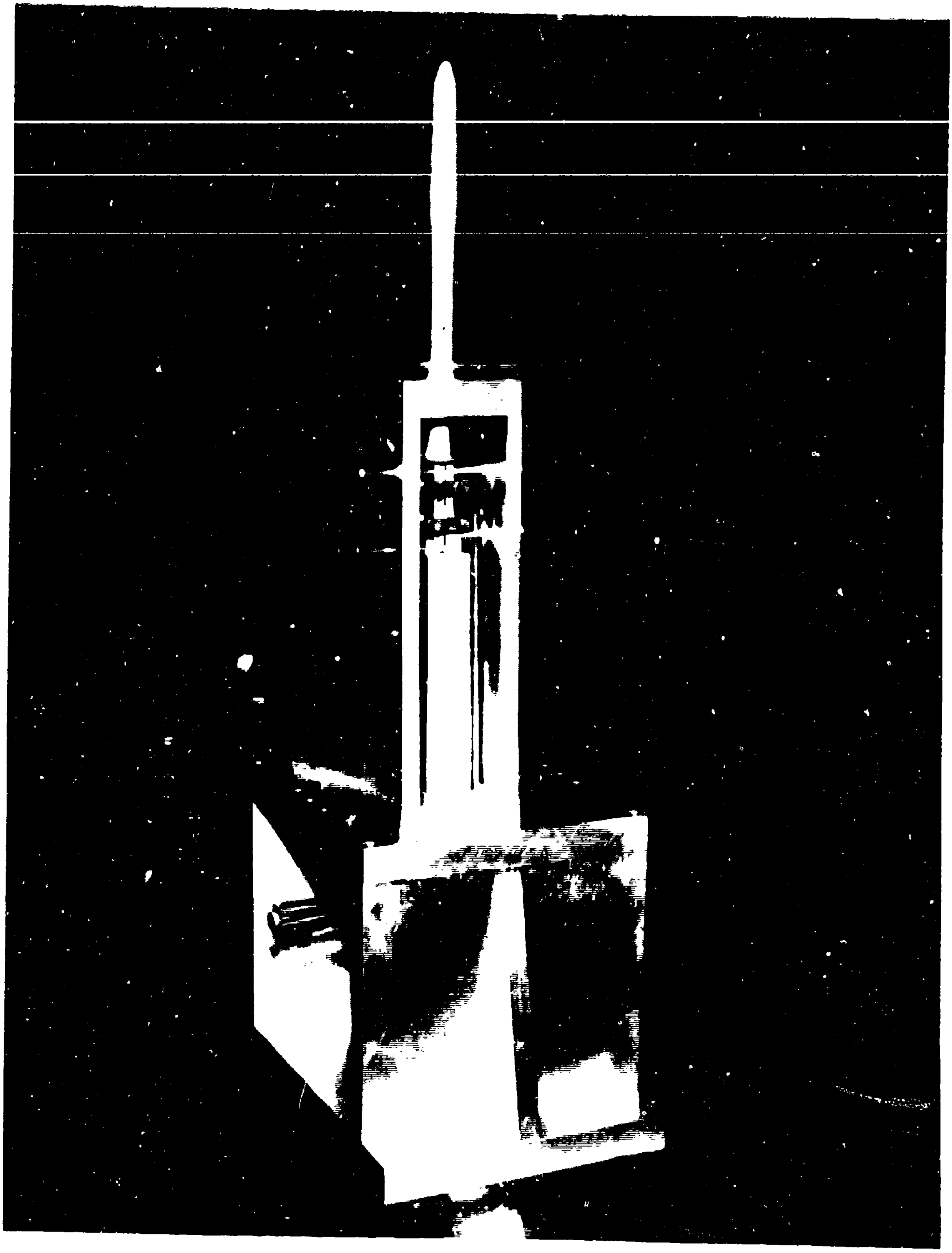


FIG. 18

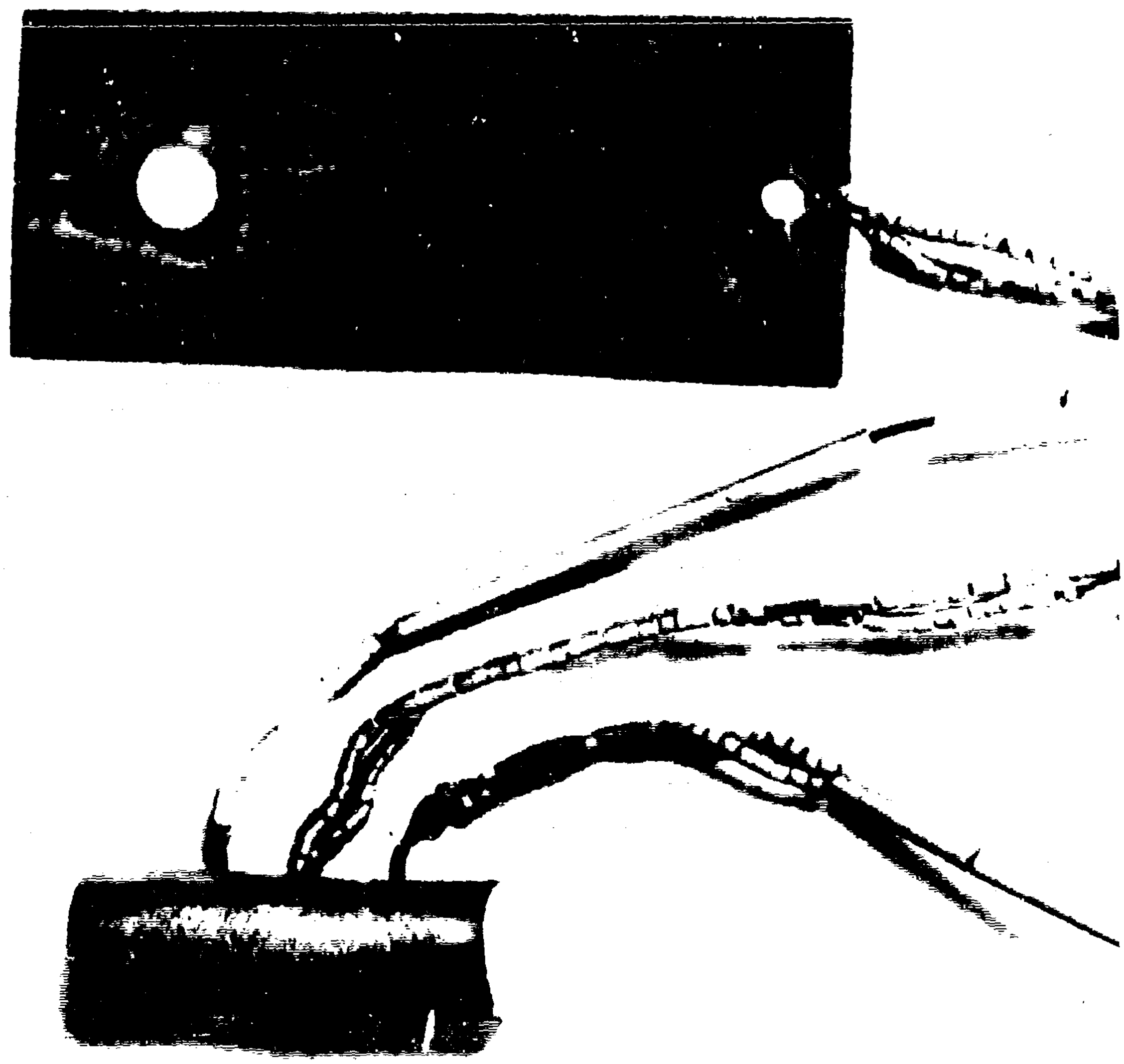


FIG. 19

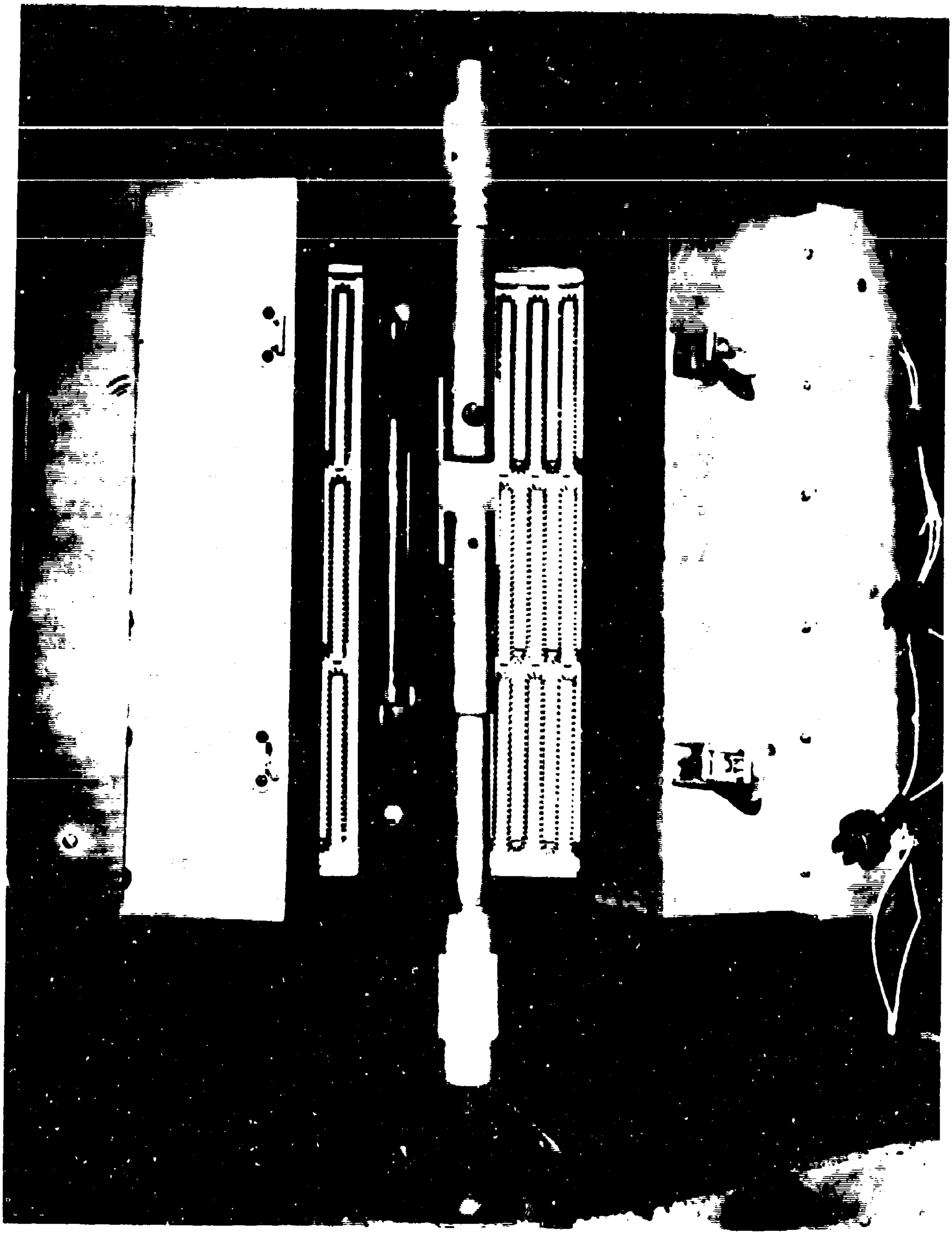


FIG. 20

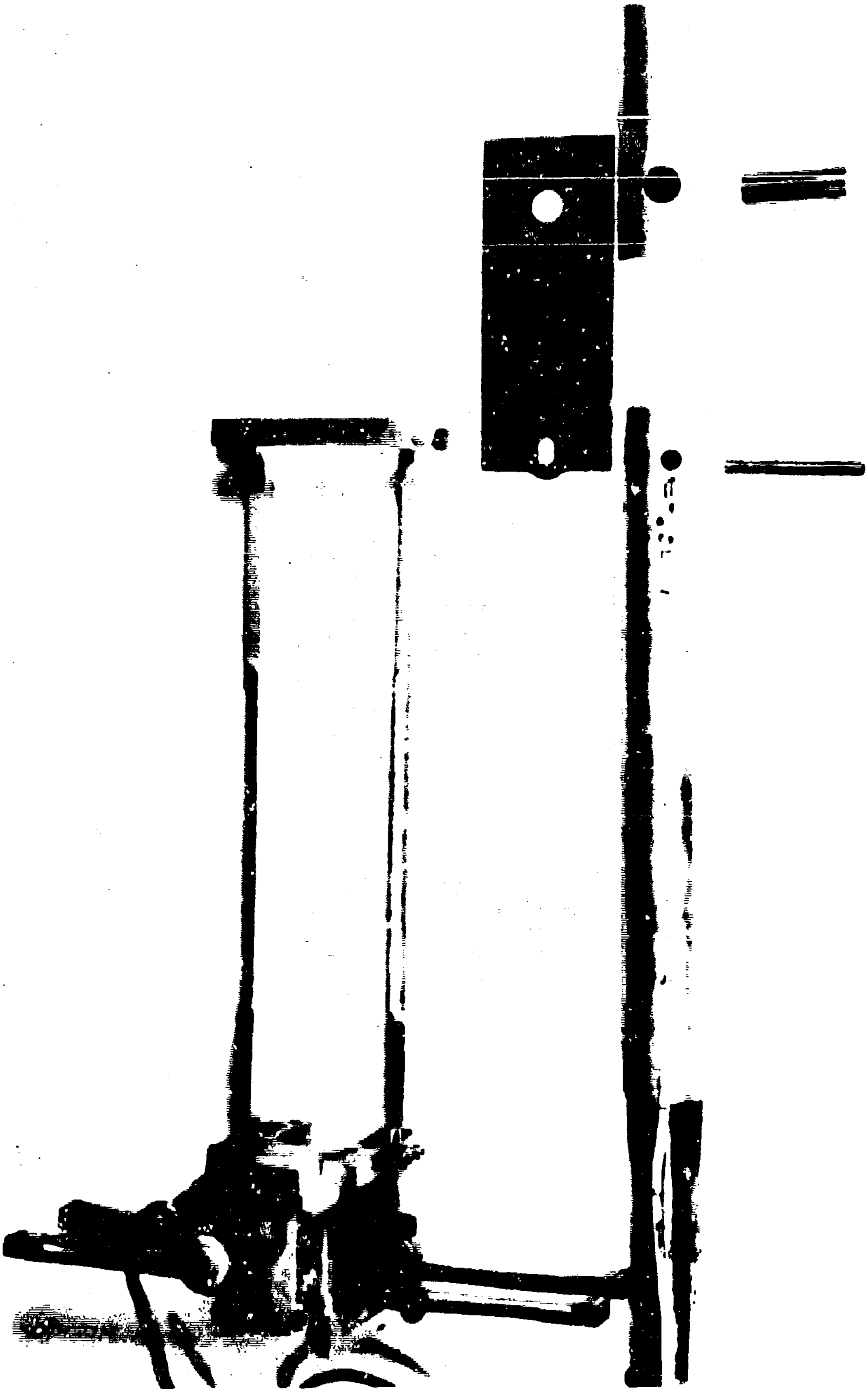


FIG. 21

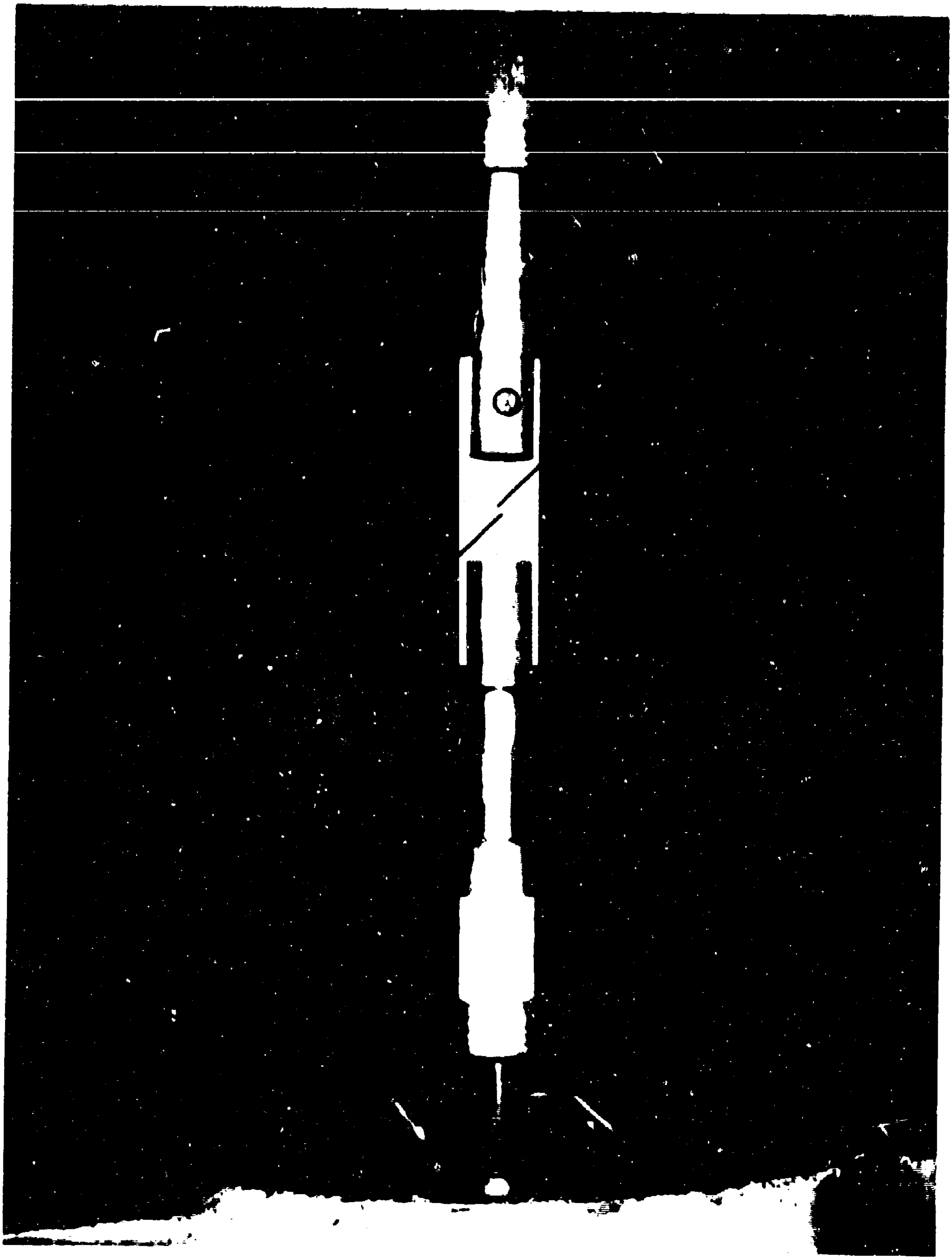


FIG. 22

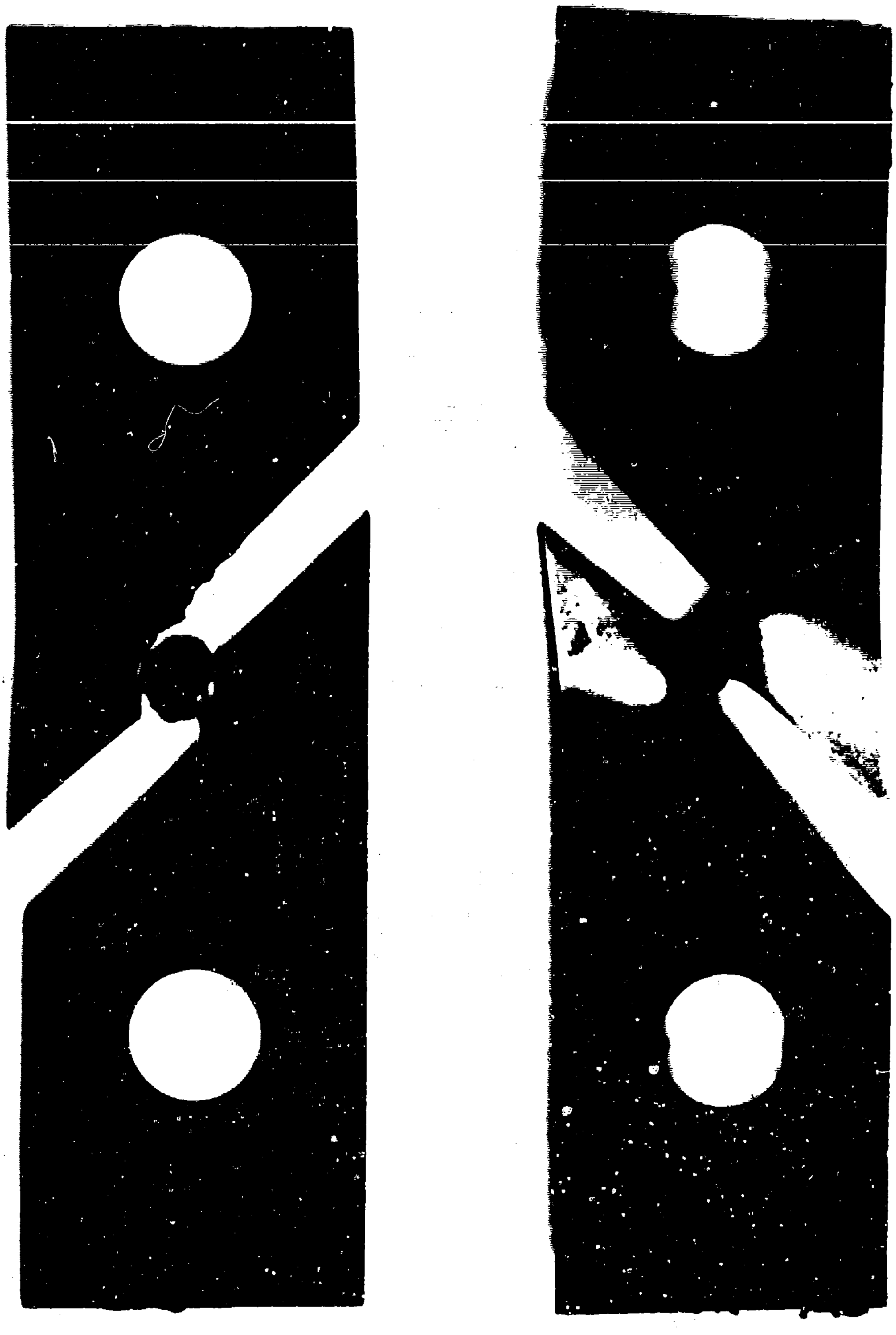
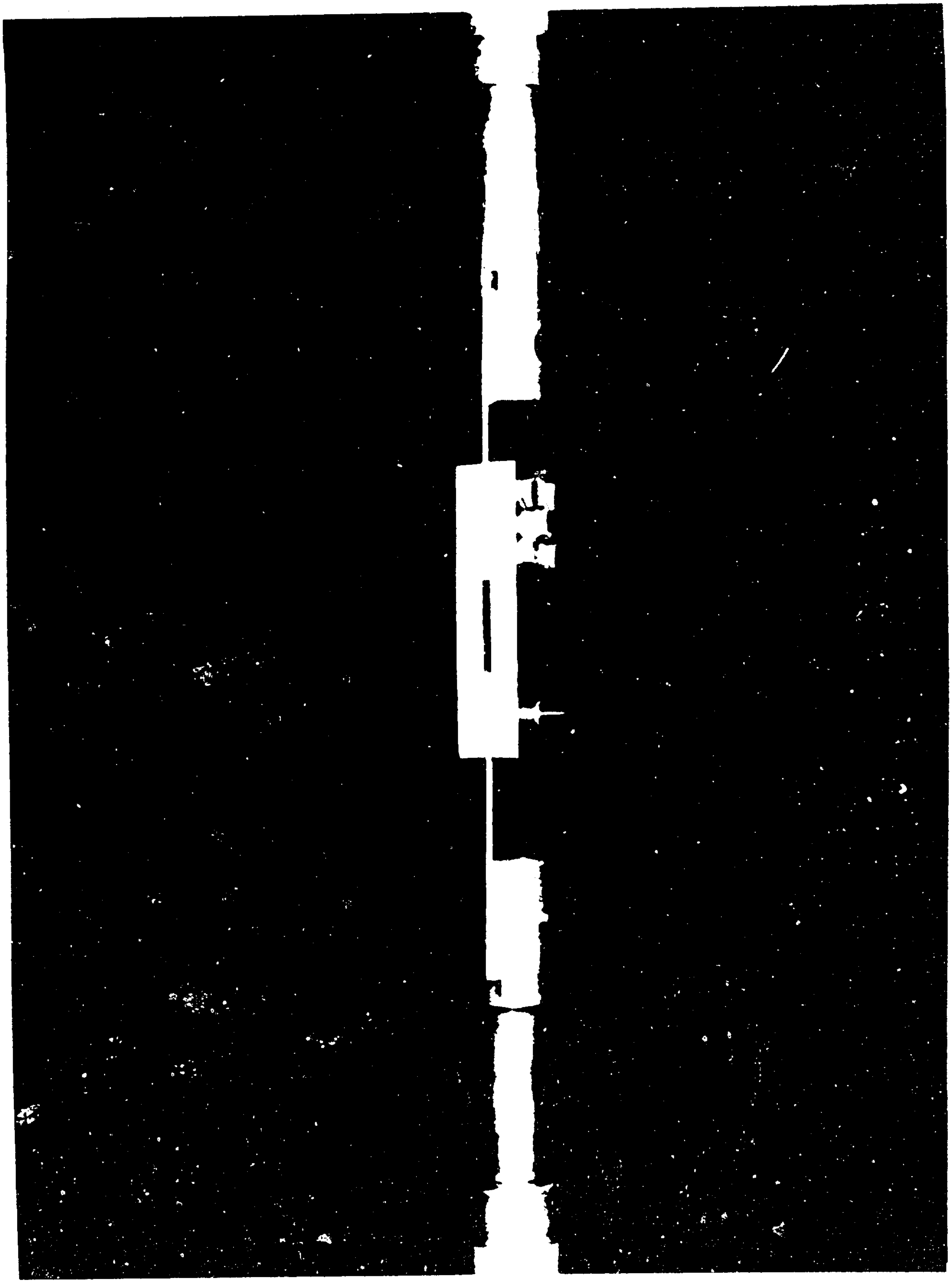


FIG. 23



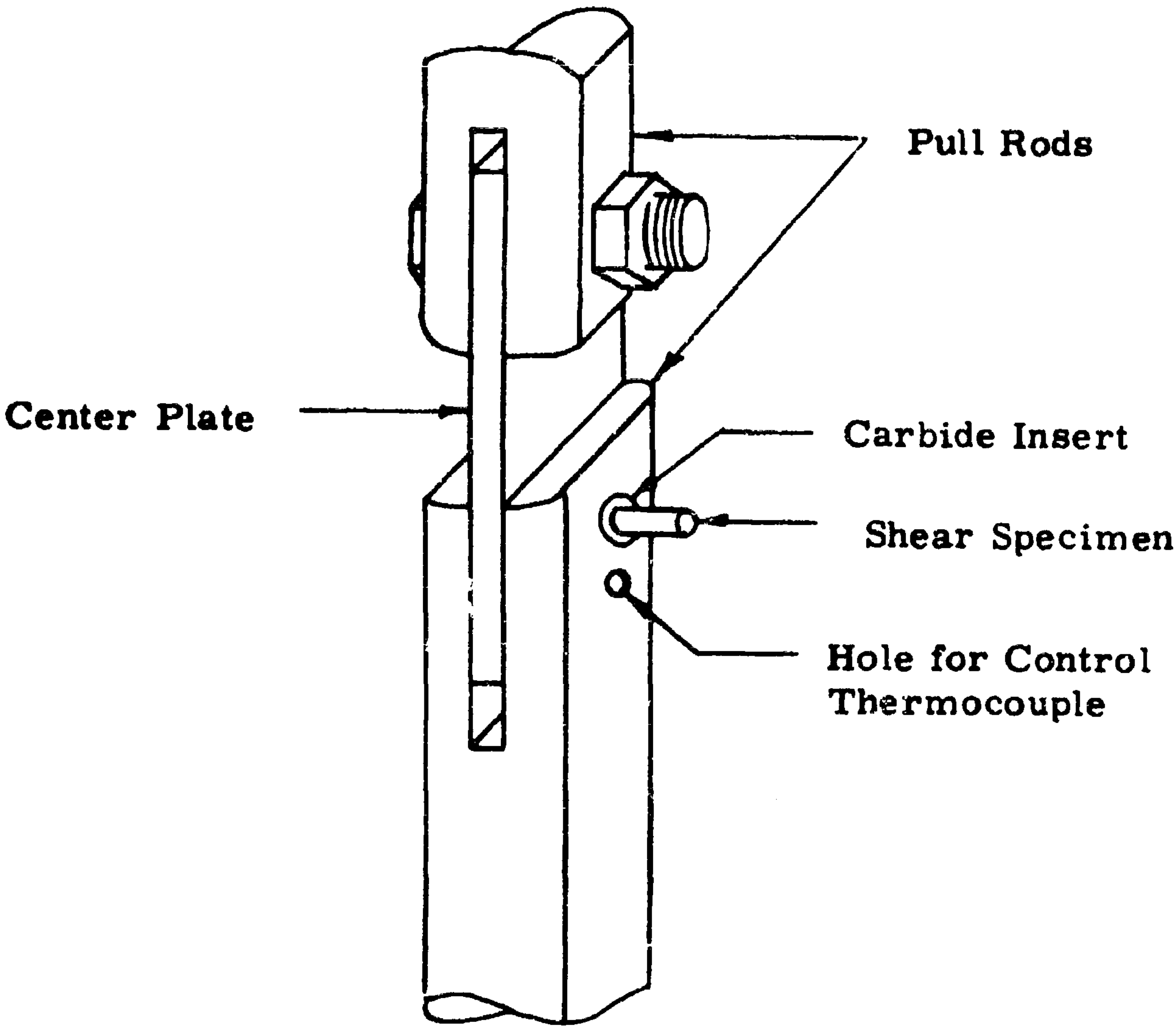
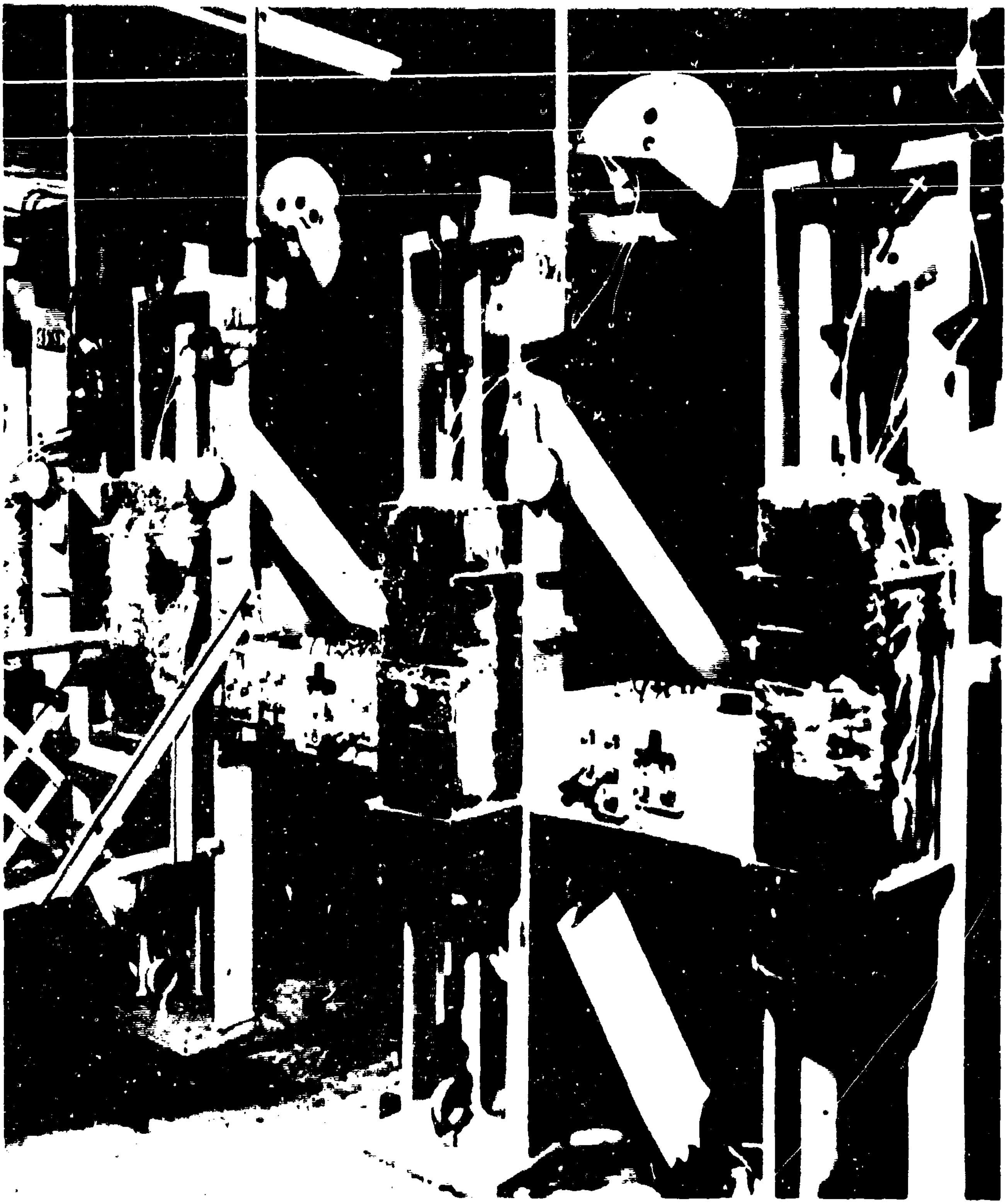

Pull Rods
Center Plate
Carbide Insert
Shear Specimen
Hole for Control Thermocouple

FIG. 25



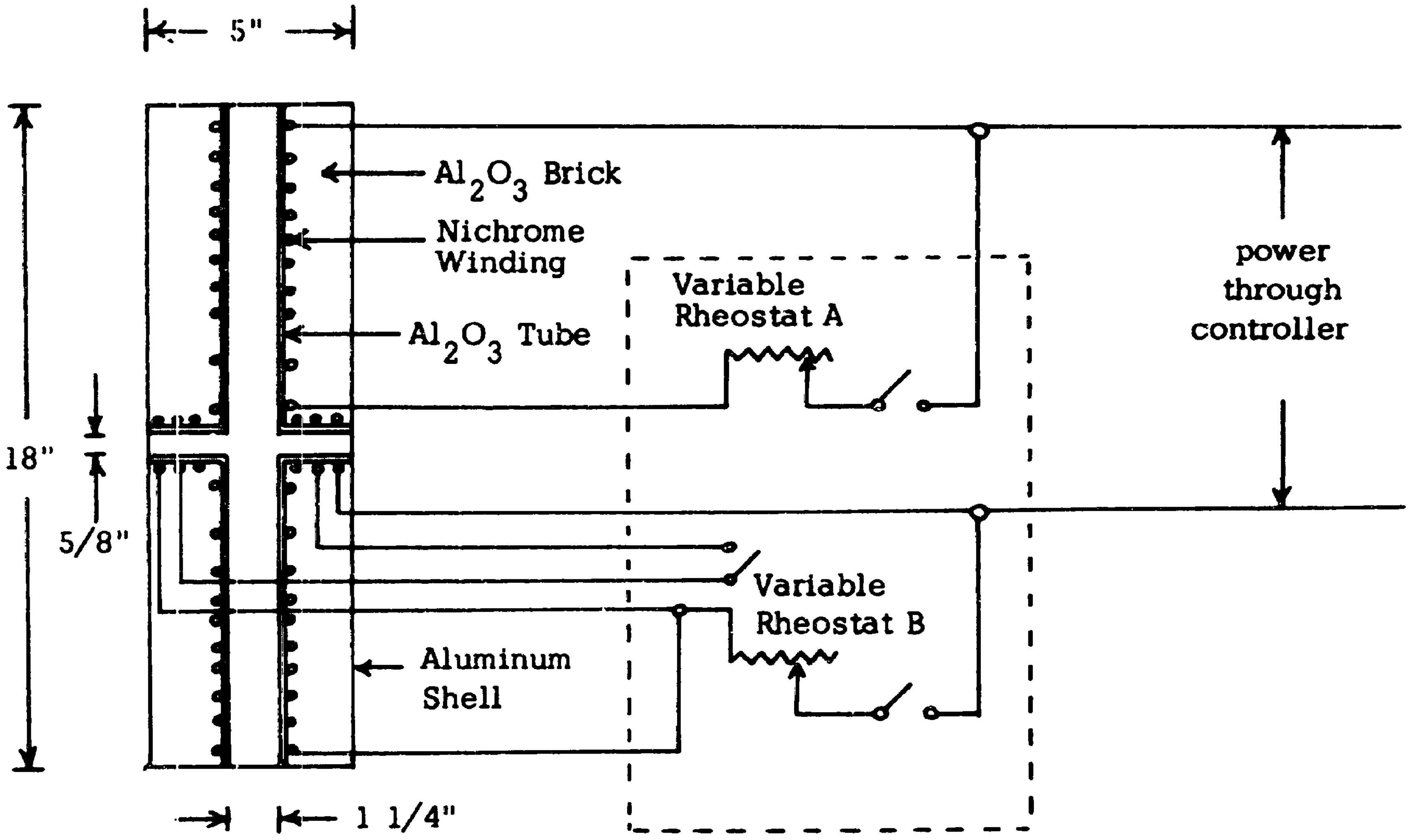

5"
18"
5/8"
1 1/4"
Al_2O_3 Brick
Nichrome Winding
Al_2O_3 Tube
Aluminum Shell
Variable Rheostat A
Variable Rheostat B
power through controller

FIG. 26

FIG. 27

FIG. 28

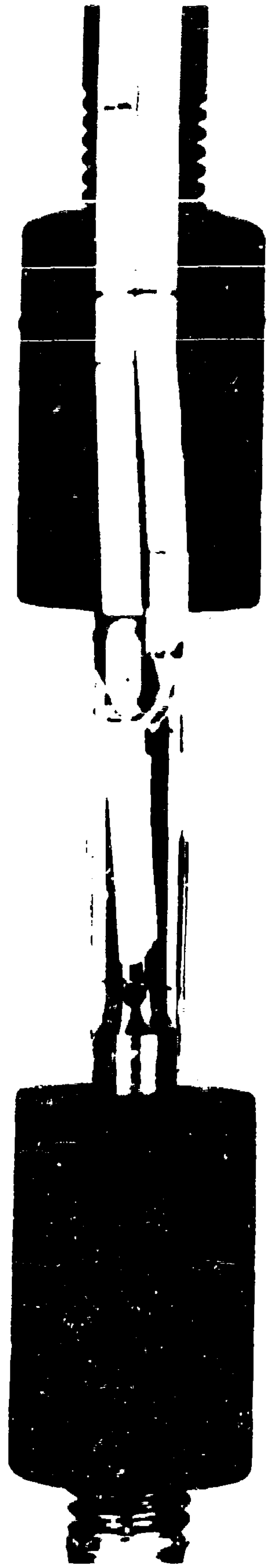


FIG. 29

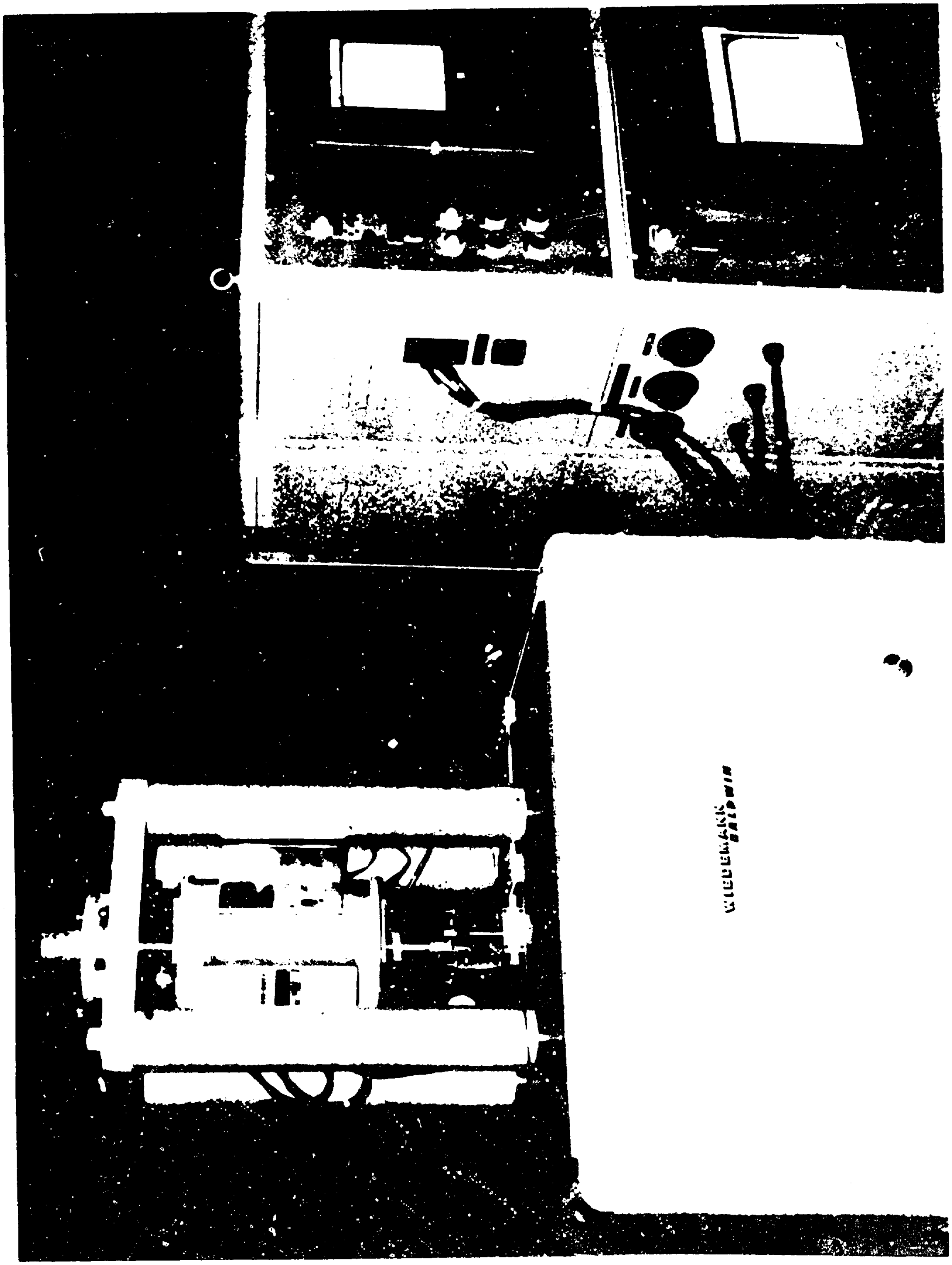


FIG. 30

FIG. 31

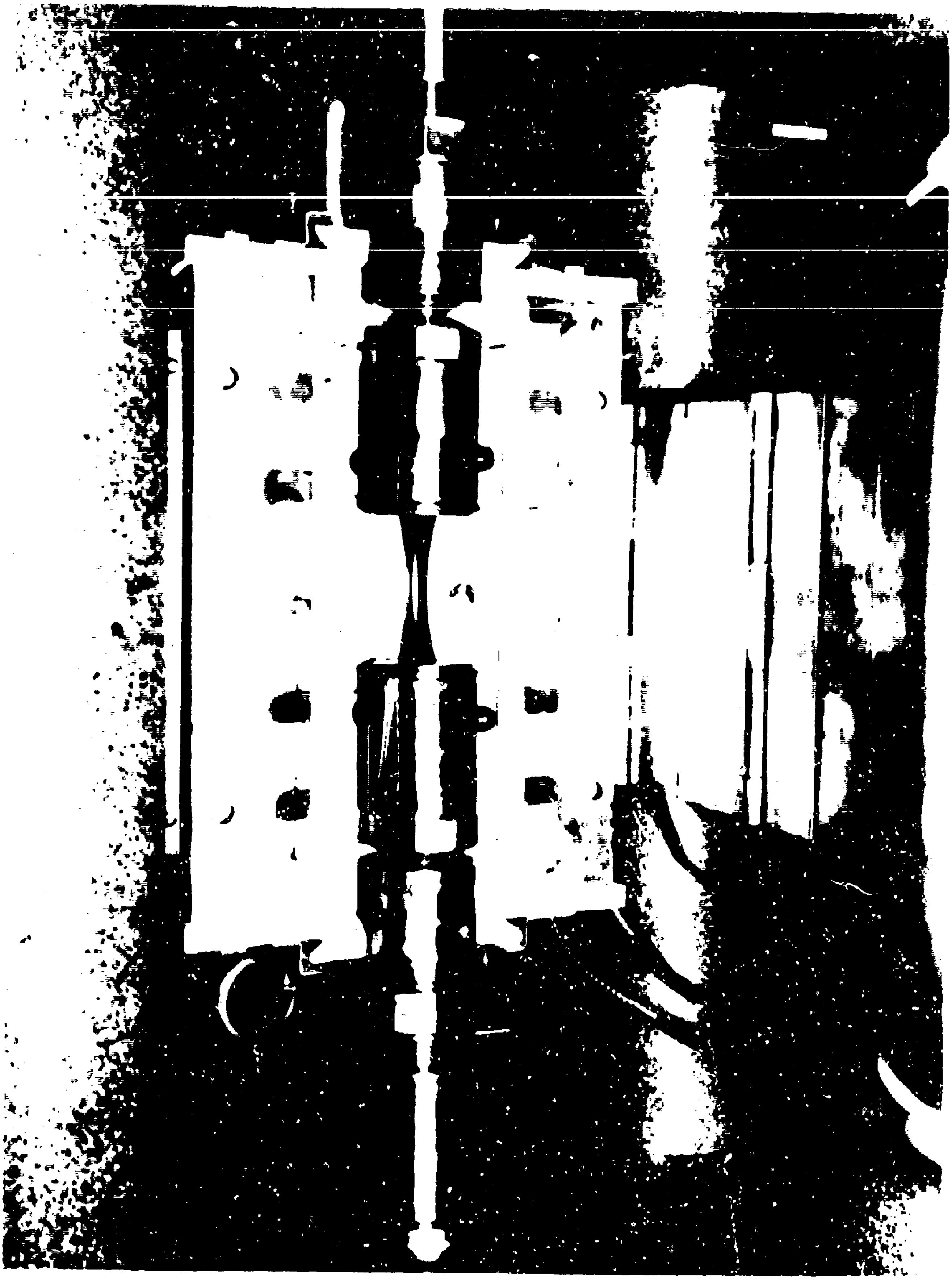
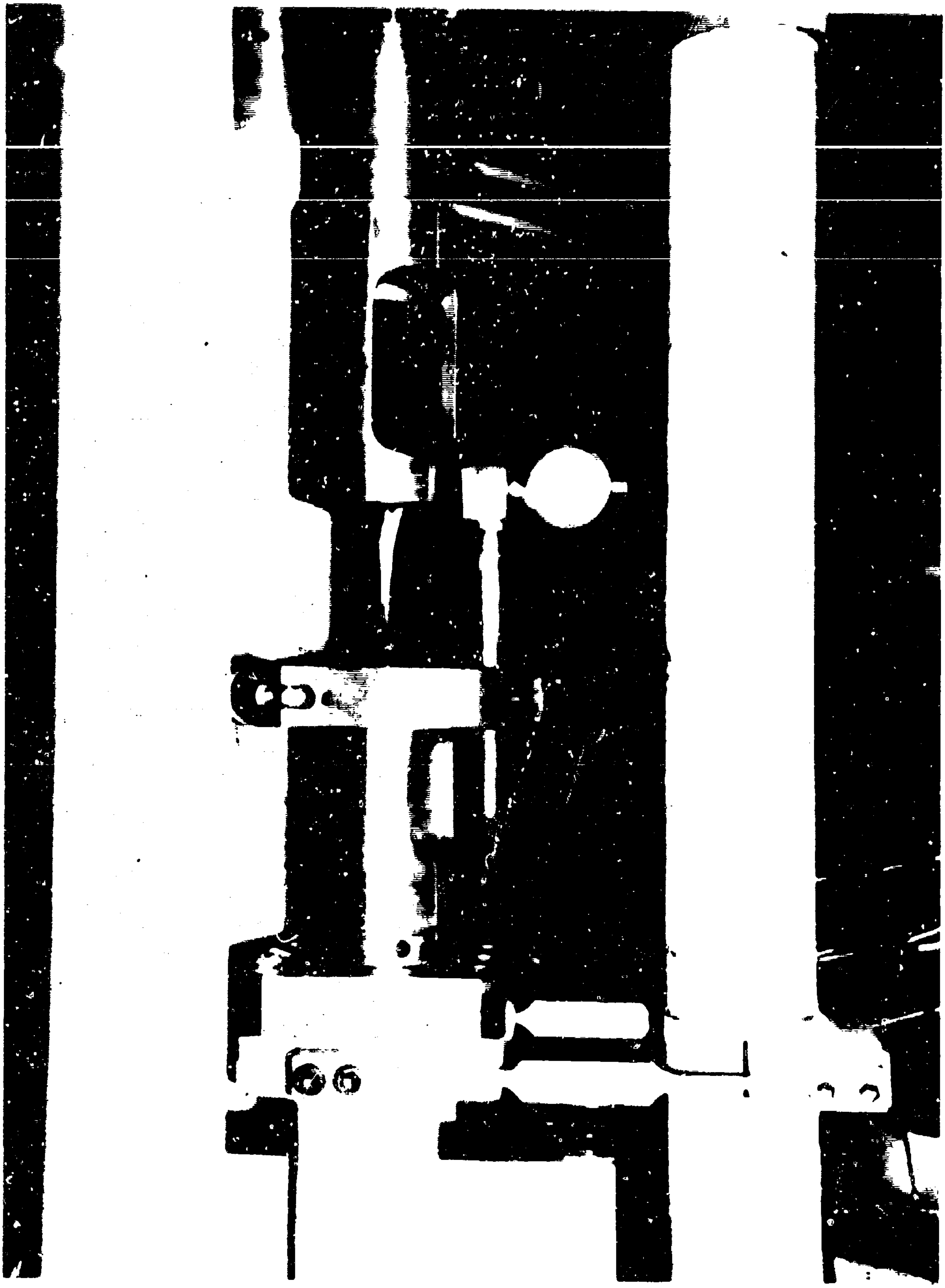


FIG. 32



SECTION VI - SUMMARY OF TEST RESULTS

SECTION VI - SUMMARY OF TEST RESULTS

6.1 Methods of Statistical Analysis

This analysis was accomplished in accordance with PROPOSED REVISIONS OF, OR ADDITION TO, CHAPTER 1 - MIL-HDBK-5(Revised March 1961) - ATTACHMENT 59-29(23), Battelle Memorial Institute.

The mechanical properties presented herein are identified by a letter (i.e., A or B) to indicate the basis upon which they were established. An 'A' value is the property above which 99 per cent of the population is expected to fall with a confidence of 95 per cent. A 'B' value is the property above which 90 per cent of the population is expected to fall with a confidence of 95 per cent.

There are two methods of obtaining these values and they are:

a. Directly Calculated Values - the directly calculated 'A' values are obtained as follows.

$$\text{'A' value} = \bar{x} - KS_x \qquad (1)$$

$$\text{where } \bar{x} = \frac{\Sigma x}{n}, \qquad (2)$$

$$S_x = \sqrt{\frac{\Sigma (x - \bar{x})^2}{(n - 1)}} \qquad (3)$$

where $\bar{x}$ is the average value of individual measurements, S_x the standard deviation of individual measurements, n the number of individual measurements and K, the one-sided tolerance factor for normal distribution and specified probability, confidence, and population (i.e., for 'A', $K = K_{.99, .95, n}$).

The 'B' values are calculated as follows:

$$\text{'B' value} = \bar{x} - KS_x \qquad (1a)$$

$$\text{where } K = K_{.90, .95, n}.$$

The values of K were obtained from the table 'One-sided Tolerance Factors for the Normal Distribution and a Confidence γ of .95', in Tables of Normal Probability Functions, N.B.S., Applied Mathematics Series 23, (1953).

An additional requirement is that the population, n, must consist of at least 100 points from a minimum of ten different heats of material. Because of the paucity of available data, this requirement usually can be satisfied for room temperature tensile ultimate and yield only.

b. Derived Values - these values are established through their relationship to directly calculated 'A' or 'B' values of F_{tu} or F_{ty} as obtained in the foregoing section. This method consists of pairing individual ultimate strength values (i.e., F_{tu}, F_{su}, F_{bru}) with individual tensile ultimate strength values, or individual yield strength values (i.e., F_{ty}, F_{bry}) with individual tensile yield strength values, determining the mean ratio of these pairs with a probability of 95 per cent and multiplying the directly calculated 'A' or 'B' values of F_{tu} or F_{ty} by this factor. Derived values are therefore equal to:

$$(\bar{r} - t_{.05} S_{\bar{r}}) \; F_{tu} \text{ (A or B)} \qquad (4)$$

or

$$(\bar{r} - t_{.05} S_{\bar{r}}) \; F_{ty} \text{ (A or B)} \qquad (5)$$

where

$$\bar{r} = \frac{\Sigma r}{n} \qquad (6)$$

$$S_{\bar{r}} = \sqrt{\frac{\Sigma (r - \bar{r})^2}{n(n-1)}} \qquad (7)$$

and $t_{.05}$ is the two-sided tolerance factor for the 't' distribution, a probability of 95 per cent and the population, n, involved. The values of $t_{.05}$ were obtained from a table in Statistical Methods for Research Workers by R. A. Fisher. The derived values of the mechanical properties have the same validity (A or B) as the values of F_{tu} or F_{ty} used in equations (4) and (5). Ten pairs of measurements (n = 10) are the minimum for establishing a derived allowable.

Statistical methods were used to establish the design allowables presented in this report. The testing performed for this program did not include specimens from a sufficient number of different heats to permit direct calculation of any of the values. Additional data was obtained from material vendors and other sources, such as inspection acceptance data, to make up this deficit. The extra data consisted of results from many heats in different forms; in many cases one specimen from each form was reported. Using the data available from all sources with each specimen as a point in the population would bias the results in favor of the heats containing a large number of data points, such as the heats tested in this program. To prevent this, a slight change was made in the method of directly calculating the allowables. The change consisted of using the average value of all the specimens in a heat-form combination as a single point in the population. The population then becomes the number of heat-form combinations instead of the number of individual specimens. The tolerance factor, K, was still chosen based upon the number of specimens. This procedure is justified by the

results obtained under this contract which show that, except for the foil gauges, there is a relatively small difference in properties from sheet to sheet, plate to plate, bar to bar, or forging to forging within a heat.

The values of all the mechanical properties of Rene' 41 (plate, bar, and forgings), Inconel 702 (sheet), and the shear ultimate of L-605 and Incoloy 901 (bar) are not statistically sound 'A' and 'B' values, and therefore are reported as tentative in the tables of MIL-HDBK-5 data.

Tables 17 to 22 indicate the populations and other pertinent information used in the calculation of the allowables.

6.1.1 LIST OF STATISTICAL SYMBOLS

A	'A' basis for mechanical property values
B	'B' basis for mechanical property values
K	one-sided tolerance factor for the normal distribution and the specified probability, confidence and population
n	the number of individual measurements or paired measurements - population
r	ratio of two paired measurements
$\bar{r}$	the average ratio of paired measurements
$S_{\bar{r}}$	standard error of paired measurement ratios
S_x	standard deviation of individual measurements
t	two-sided tolerance factor for the 't' distribution and the specified probability and population
x	value of an individual measurement
$\bar{x}$	the average value of individual measurements
Σ	the summation of

TABLE 17

Populations Used to Calculate A and B Values

Material Form & Property	Direction	Values Obtained	Method	Number of: Heat-Form Combinations	Pairs	Heats	Vendors	Different Thicknesses	Specimens
Rene'41									
Foil									
F_{tu}	L	A* & B*	Derived	-	55	3	1	2	55
	T	A & B	Direct	46	-	45	3	3	306
F_{ty}	L	A* & B*	Derived	-	55	3	1	2	55
	T	A & B	Direct	46	-	45	3	3	306
Sheet									
F_{tu}	L	A* & B*	Derived		86	3	1	3	86
	T	A & B	Direct	206	-	204	5	7	1089
F_{ty}	L	A* & B*	Derived		85	3	1	3	85
	T	A & B	Direct	206	-	204	5	7	1089
F_{cy}	L	A* & B*	Derived	-	79	3	1	3	79
	T			-	87	3	1	3	87
F_{su}	L			-	76	3	1	3	76
	T			-	83	3	1	3	83
F_{bru}(e/D=1.5)	L			-	30	3	1	1	30
	T			-	78	3	1	3	78
F_{bry}(e/D=1.5)	L			-	30	3	1	1	30
	T			-	76	3	1	3	76
F_{bru}(e/D=2.0)	L			-	30	3	1	3	30
	T			-	83	3	1	3	83
F_{bry}(e/D=2.0)	L			-	30	3	1	1	30
	T	A* & B*	Derived	-	82	3	1	3	82

TABLE 18

Populations Used to Calculate A and B Values

Material Form & Property	Direction	Values Obtained	Method	Number of Heat-Form Combinations	Number of Pairs	Number of Heats	Number of Vendors	Number of Different Thicknesses	Number of Specimens
Rene'41									
Plate, Bar & Forging									
F_{tu}	L	A^1 & B^1	Direct	15	-	6	1	5	145
F_{ty}	L	A^1 & B^1	Direct	15	-	6	1	5	145
F_{cy}	L	A^2 & B^2	Derived	-	105	6	1	4	105
Plate & Forging									
F_{tu}	T	A^2 & B^2	Derived	-	84	6	1	3	84
F_{ty}	T			-	82	6	1	3	82
F_{cy}	T			-	53	6	1	2	53
F_{su}	L			-	40	6	1	2	40
	T			-	44	6	1	2	44
F_{bru}(e/D=1.5)	T			-	20	3	1	1	20
F_{bry}(e/D=1.5)	T			-	20	3	1	1	20
F_{bru}(e/D=2.0)	T			-	25	3	1	1	25
F_{bry}(e/D=2.0)	T	A^2 & B^2		-	25	3	1	1	25
Bar F_{su}	T	A^3 & B^3	Derived	-	30	2	1	2	30

TABLE 17

TABLE 19

Populations Used to Calculate A and B Values

Material Form & Property	Direction	Values Obtained	Method	Number of: Heat-Form Combinations	Pairs	Heats	Vendors	Different Thicknesses	Specimens
L-605									
Sheet									
F_{tu}	L	A^* & B^*	Derived	-	69	3	1	3	69
	T	A & B	Direct	211	-	80	1	3	370
F_{ty}	L	A* & B*	Derived	-	69	3	1	3	69
	T	A & B	Direct	211	-	80	1	3	370
F_{cy}	L	A* & B*	Derived	-	69	3	1	3	69
	T			-	69	3	1	3	69
F_{su}	L			-	27	3	1	2	27
	T			-	30	3	1	2	30
F_{bru}(e/D=1.5)	L			-	20	3	1	1	20
	T			-	68	3	1	3	68
F_{bry}(e/D=1.5)	L			-	19	3	1	1	19
	T			-	68	3	1	3	68
F_{bru}(e/D=2.0)	L			-	16	3	1	1	16
	T			-	67	3	[illegible]	3	67
F_{bry}(e/D=2.0)	L			-	16	3	1	1	16
	T	A* & B*	Derived	-	67	3	1	3	67
Plate, Bar & Forging									
F_{tu}	L	A & B	Direct	181	-	92	1	17	305
F_{ty}	L	A & B	Direct	181	-	92	1	17	305
F_{cy}	L	A* & B	Derived	-	69	6	1	3	69

TABLE 20

Populations Used to Calculate A and B Values

Material Form & Property	Direction	Values Obtained	Method	Number of Heat-Form Combinations	Number of Pairs	Number of Heats	Number of Vendors	Number of Different Thicknesses	Number of Specimens
L-605									
Plate & Forging									
F_{tu}	T	A & B	Direct	87	-	78	1	10	174
F_{ty}	T	A & B	Direct	87	-	78	1	10	174
F_{cy}	T	A* & B*	Derived	-	39	6	1	2	39
	L	A* & B*		-	45	6	1	2	45
F_{su}	T	A* & B*		-	45	6	1	2	45
F_{bru}(e/D=1.5)	T	A* & B*		-	12	3	1	1	12
F_{bry}(e/D=1.5)	T	A* & B*		-	12	3	1	1	12
Bar									
F_{su}	T	A^4 & B^4	Derived	-	30	3	1	2	30

TABLE 21

Populations Used to Calculate A and B Values

Material Form & Property	Direction	Values Obtained	Method	Number of Heat-Form Combinations	Number of Pairs	Number of Heats	Number of Vendors	Number of Different Thicknesses	Number of Specimens
Inconel 702									
Sheet									
F_{tu}	L	A^2 & B^2	Derived	-	57	3	1	2	57
	T	A^1 & B1	Direct	29	-	19	1	8	82
F_{ty}	L	A^2 & B^2	Derived	-	57	3	1	2	57
	T	A^1 & B^1	Direct	29	-	19	1	8	82
F_{cy}	L	A^2 & B^2	Derived	-	54	3	1	2	54
	T			-	56	3	1	2	56
F_{su}	L			-	48	3	1	2	48
	T			-	27	3	1	2	27
F_{bru}(e/D=1.5)	L			-	29	3	1	1	29
	T			-	57	3	1	2	57
F_{bry}(e/D=1.5)	L			-	29	3	1	1	29
	T			-	57	3	1	2	57
F_{bru}(e/D=2.0)	L			-	29	3	1	2	29
	T			-	57	3	1	2	57
F_{bry}(e/D=2.0)	L			-	29	3	1	1	29
	T	A^2 & B^2	Derived	-	57	3	1	2	57

TABLE 22

Populations Used to Calculate A and B Values

Material Form & Property	Direction	Values Obtained	Method	Number of Heat-Form Combinations	Number of Pairs	Number of Heats	Number of Vendors	Number of Different Thicknesses	Number of Specimens
Incoloy 901									
Bar & Forging									
F_{tu}	L	A & B	Direct	46	-	39	4	3	166
F_{ty}	L	A & B	Direct	46	-	39	4	3	166
F_{cy}	L	A* & B*	Derived	-	88	3	1	3	88
Forging									
F_{tu}	T			-	30	3	1	1	30
F_{ty}	T			-	30	3	1	1	30
F_{cy}	T			-	30	3	1	1	30
F_{su}	L			-	15	3	1	1	15
	T	A* & B*		-	15	3	1	1	15
Bar									
F_{su}	T	A^4 & B^4	Derived	-	59	3	1	2	59

NOTES:

A, B	Directly calculated values (as described in text).
A*, B*	Derived values (as described in text).
A^1, B^1	Value obtained using same procedure as directly calculated values except that the data did not cover the minimum number of different heats, (i.e., ten), or else the population was not large enough. These values are not statistically sound A and B values.
A^2, B^2	Derived values based on A^1, B^1 values of F_{tu} and F_{ty}. These values are not statistically sound A and B values.
A^3, B^3	Values obtained in manner similar to derived values except that data from the transverse direction was paired with tensile ultimate data from the longitudinal direction. These values are not statistically sound A and B values.
A^4, B^4	Values obtained in manner similar to derived values except that data from the transverse direction was apired with tensile ultimate data from the longitudinal direction. These values are not statisitically sound A and B values.

6.2 Data Presentation

6.2.1 Effect of Temperature on Strength (1/2 Hour Exposure) -

These curves are presented as 'Per Cent Strength at Room Temperature vs Test Temperature'. The procedure used to obtain these curves is as follows.

a. Plot the range of values (i.e., minimum to maximum) for the property at each temperature. Note: The elevated temperature tests were run on specimens from one heat only, and therefore the room temperature range is plotted for this heat only.

b. Indicate the average value at each temperature.

c. Indicate the value 5 per cent above the minimum value at each temperature.

d. Draw the curve passing through the average or 5 per cent above minimum value whichever is lowest at each temperature.

e. Obtain the curve value at each temperature as a percentage of the curve value at room temperature.

f. Plot the per cent values and fit the curve.

To obtain a smooth curve in step (d), engineering judgement was used and the curves do not necessarily pass through the stated values at each temperature.

6.2.2 Effect of Exposure at Elevated Temperature on the Elevated Temperature Strength -

These curves are presented as 'Per Cent Strength of Room Temperature vs Temperature'; they show the effect of exposure time at temperature on the elevated temperature properties. Each of these figures contains a number of curves - one for each exposure time. The curves are drawn for each exposure time using the same technique as described in the foregoing section, and are plotted on the same graph for easy comparison.

6.2.3 Effect of Exposure at Elevated Temperature on Room Temperature Properties -

These curves are presented in 'Per Cent Strength at Room Temperature vs Exposure Temperature'; they show the effect on the properties of specimens tested at room temperature after exposure to elevated temperature. These curves are drawn using the same technique described in the preceding sections.

6.2.4 Stress-Strain Curves

The method used to obtain these curves is as follows:

a. A smooth, well defined curve typical of those obtained during testing was selected and repictted on regular graph paper.

b. Percentages were taken of the .2 per cent yield strength and the plastic strains required to obtain these values were noted.

c. The modulus to be used was selected by comparison between data generated in this program and data in published literature.

d. The 'A' value of the yield strength was used as the room temperature value in these curves; the percentage of the 'A' value to be used at elevated temperature was obtained from the appropriate figure.

e. The straight line portion of the curve was drawn using the selected modulus and then the remaining portion of the curve was plotted using the plastic strains noted in step (b) and the percentage of the appropriate yield strength.

6.3 Room Temperature Tensile Strength Distribution

This investigation did not contemplate conducting an analysis of variance to determine the contribution of such factors as testing, form, vendor, etc. to the overall variance of a given alloy. Such an analysis normally expressed in terms of root mean square deviations of individual observations from their mean would be beyond the scope of this program. However, in order to indicate the manner in which some of these factors may be influencing strength variations, the range of values (the lowest and highest values) are plotted against some of the more significant variables (i.e., heat, form, etc.). The presentation incorporates all data including testing accomplished under this contract as well as data available from other sources.

Only room temperature values are plotted since these data are least likely to be influenced by testing techniques and there seems to be a fairly good correlation between this parameter and other properties such as shear strength, bearing strength, etc. In addition, the elevated temperature strength in a uniform material will normally be proportional to the room temperature strength at least out to some critical temperature range.

This method of presentation has its limitations and in some instances, may lead to some confusion particularly when one considers that a plot of the range of values found within a heat will incorporate (in some instances) the range found from sheet to sheet within the heat as well as the range within a sheet. It does, nevertheless, give a good indication as to which factors are the predominating ones. If, for example, the range of values for a given vendor and gauge thickness is 30,000 psi from heat to heat, 10,000 psi from sheet to sheet within a heat and 5,000 psi with a sheet, it is safe to assume that if the number of observations is adequate in all categories that the greatest variation in strength results from the heat composition.

6.3.1 Material Rene' 41

The range of room temperature tensile properties found within a single sheet, bar or forging are shown in Figure 33. Specimens were taken so as to survey the form in a random manner and only those values are plotted where a sufficient number of specimens were tested to make the data meaningful. The letter designation applies to the heat involved and repetitive letters indicate the same heat. All heats were produced by the General Electric Company.

Figure 33 indicates very little difference, if any, between longitudinal and transverse properties except for the significantly lower transverse strength in 1 x 3 inch forgings. The spread in values is relatively small, particularly in sheet gauges .020 to .080 inches. The AMS specification requirements were satisfied as to room temperature yield strength for all forms. The same is true of the ultimate strength except for one 1 x 3 inch forging from heat F.

The range of room temperature tensile properties found from sheet to sheet within a single heat are presented in Figures 34 thru 37 broken down by Producer. Most of these data were collected by the Quality Control Laboratory of Republic Aviation Corporation as part of incoming inspection of production material over the last two years and as such are considered representative of the current quality of the alloy in sheet form. The number of sheets per heat is indicated for each gauge thickness. In the majority of cases, only one specimen was tested for each sheet and this in the direction transverse to the grain flow.

The maximum spread in values in Vendor A material, Figure 34 occurred in the 13 sheets of .050 inch material; however, the direction of scatter is favorable in that it is toward higher tensile properties (i.e., the lowest points are 140,000 psi yield, 190,000 psi ultimate). All points satisfy AMS specification requirements.

Only .013 and .025 sheets were purchased from Vendor B. The .013 inch material exhibits generally lower properties than the .025 inch material, however, this may be attributed to the difficulty in testing thin gauge material. In any event, all tests satisfy the AMS requirements except for minor deficiencies in the tensile yield (lowest value obtained 127,000 psi). Vendor C material (.020, .025, and .032 inch sheet) shows remarkedly little scatter. All values satisfy AMS yield and ultimate strength requirements. Ranges for V ndors B and C are shown in Figures 35 and 36 respectively.

Vendor D material (.020, .025, .032 and .050 inch) exhibits a normal scatter pattern except where the spread is large (i.e., the 21 sheets

from the .025 inch material), the values extend significantly below the AMS minimum requirements. Some of the actual values obtained which are typical of this scatter when it occurs are shown in Table 23. The remarkable feature of this data is the consistency within a given sheet, as well as the consistency from sheet to sheet among the rejects. Rejects are generally tested with two additional specimens from the same sheet so that repetitive sheet numbers in the table represent the same sheet. Figure 37 shows range of values.

Figure 38 shows the variation from heat to heat, analyzed by vendor and gauge, and includes all data points available within a given heat. The number of heats per gauge are shown in parenthesis. All values from material produced by Vendors A, B, and C were above the specification minimums with the exception of the .013 inch material from Vendor B. In this latter case, approximately 3 sheets out of 233 did not satisfy the 130,000 psi minimum yield strength (the lowest value obtained being 123,000 psi). Vendor D material as anticipated shows the lowest values for .025, .032 and .050 inch material; the .020 and .070 inch sheet from the same vendor does not exhibit this deficiency. While the material which did not meet the strength requirements of the applicable AMS specification was rejected by Quality Control, the values obtained were used in the calculation for 'A' and 'B' properties.

It is interesting to note the erroneous conclusions that can result if a full picture of material variation is not known when a calculation is made for 'A' and 'B' values for MIL HDBK-5. For example, there were approximately 90 data points from 8 heats available for establishing room temperature tensile strength in the longitudinal direction. Since this population is very close to the minimum requirements of Reference 114, the 'A' and 'B' values directly calculated would give the following:

		A	B
F_{tu}	Long.	188.2	193.5
F_{ty}	Long.	139.9	145.5

The 'A' and 'B' values directly calculated for the transverse direction are as follows:

		A	B
F_{tu}	Trans.	177.7	185.8
F_{ty}	Trans.	123.6	134.0

Figure 38 however, shows that there is very little difference between longitudinal and transverse properties. The reason for the discrepancy is that all of the data for the longitudinal analysis came from 2 of 3 vendors with demonstrated

superior tensile strength while the transverse data includes the low values from Vendor D (longitudinal properties were not available from Vendor D). A substantial upgrading in minimums would have resulted if these later values were eliminated from the transverse 'A' and 'B' analysis. For this reason, the longitudinal 'A' and 'B' values reported were derived from the transverse values as being more representative of the actual strengths.

While this presentation only considers room temperature tensile data, the trend established persists at least up to 1400°F. Typical values for room temperature versus 1400°F are presented in Tables 23 for Vendor D material.

6.3.2 Material L-605

The range of room temperature tensile properties found within a single sheet, plate, bar or forging are shown in Figure 39. The presentation for this figure as well as Figures 40, 41 and 42 follow the same format as Rene' 41.

Referring to Figure 39, the degree of scatter is negligible except for the foil gauges (i.e., .005 and .010 inches). The longitudinal properties are somewhat higher than the transverse in sheet thicknesses and considerably higher in foil. With the exception of the foil gauges, form does not seem to exert any significant influences on strength.

The range of room temperature tensile properties from sheet to sheet within a heat are presented in Figure 40. Once again the foil gauges exhibits the greatest spread in values.

The range of values from heat to heat within a given thickness is shown in Figure 41 for bar, plate and forgings in the longitudinal direction, and this data was collected by the Haynes Stellite Company as part of their quality control inspection. The range of properties for the heats evaluated under this contract are indicated by an 'x' on the graphs.

In general, the uniformity of the alloy is excellent considering the number of heats represented, and all values satisfy the AMS specification requirements.

6.3.3 Material Inconel 702

The range of room temperature tensile strength found within a single sheet is shown in Figure 43. All material was purchased from the International Nickel Company. The foil was reduced from .020 to .005 inches by the Hamilton Watch Company.

The .005 inch material is considerably lower in strength than the .020 and .040 inch materials. The .040 inch material is very uniform in strength and does not show any difference in tensile strength between the longitudinal and transverse directions. The .020 inch sheet in this respect is very erratic and somewhat heat dependent. The longitudinal strength is lower in heat C, higher in heat B, and the same in heat A with respect to the transverse direction. The longitudinal and transverse strength are the same for .005 inch foil. The largest spread in values occurs in the .020 inch sheet; however, the tendency is toward higher strength particularly in the longitudinal direction, and the degree appears to be a function of the heat involved. The B heat for example, exhibits the largest spread in both the .020 and .005 inch thicknesses.

The range within a heat and from heat to heat is shown in Figures 44a and b respectively. Again, this data is limited but the spread within a category does not appear to be excessive.

6.3.4 Material Incoloy 901

The range of values from room temperature tension and compression yield strengths found within a single bar or forging are shown in Figure 45. The spread appears to depend on the heat analyzed. Heat E exhibits the maximum range in all 3 forms tested (e.g., .5 inch, 1 inch bar, and 1 x 3 inch forging). In general, the strength within a heat appears to be independent of section size. (Heat F is a good illustration.)

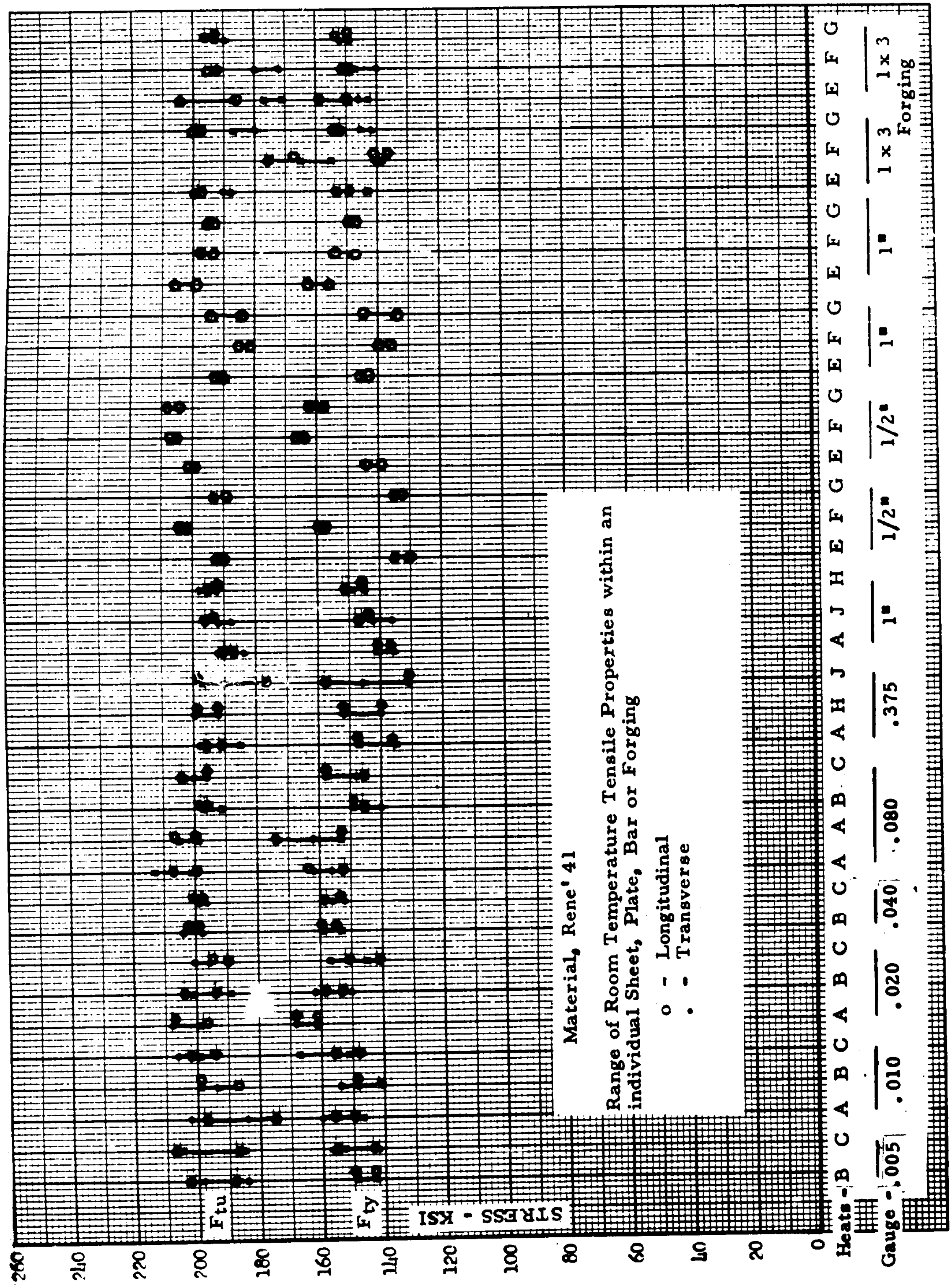
Figure 46 presents the range of tensile properties compared on a heat to heat basis for a given section size. The number of heat per gauge is shown in parenthesis. Letter designations are used to represent different vendors which are not the same as those analyzed under Rene' 41. The heat range from Vendor A material includes the variation within a single bar or forging whereas the others do not. This is responsible for the greater range exhibited by Vendor A even though a lesser number of heats were evaluated.

The limited data available for this analysis would suggest that the maximum variation in properties can occur within a given bar or forging, and that the spread is a heat characteristic, the variation from heat to heat does not appear to be excessive.

6.3.4.1 Compression

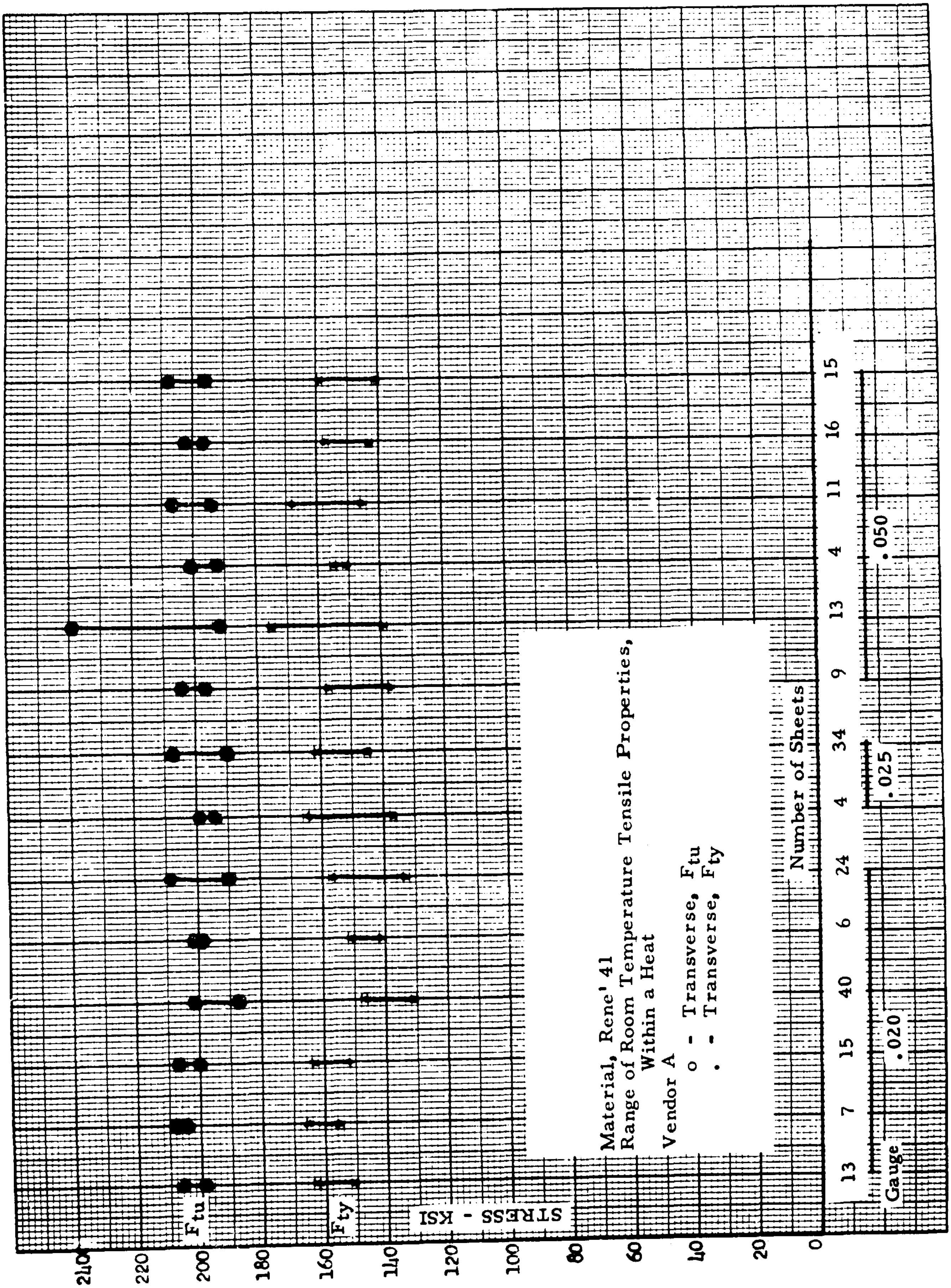
The range of room temperature compression yield strength within a given heat for Rene' 41, L-605 and Inconel 702 are shown in Figures 47 - 49.

FIG. 33



Material, Rene' 41
Range of Room Temperature Tensile Properties within an individual Sheet, Plate, Bar or Forging
o - Longitudinal
. - Transverse
STRESS - KSI
Ftu
Fty
0 20 40 60 80 100 120 140 160 180 200 220 240 260
Heats - B C A B C A B C A B C B C A C A A B C A H C A H J A J H E F G E F G E F G E F G E F G E F G E F G
Gauge - .005 .010 .020 .040 .080 .375 1" 1/2" 1/2" 1" 1" 1 x 3 1 x 3 Forging

FIG. 34



Material, Rene' 41
Range of Room Temperature Tensile Properties, Within a Heat
Vendor A
o - Transverse, F_{tu}
. - Transverse, F_{ty}
Number of Sheets
13 7 15 40 6 24 4 34 9 13 4 11 16 15
Gauge
.020
.025
.050
STRESS - KSI
240 220 200 180 160 140 120 100 80 60 40 20 0
F_{tu}
F_{ty}

FIG. 35

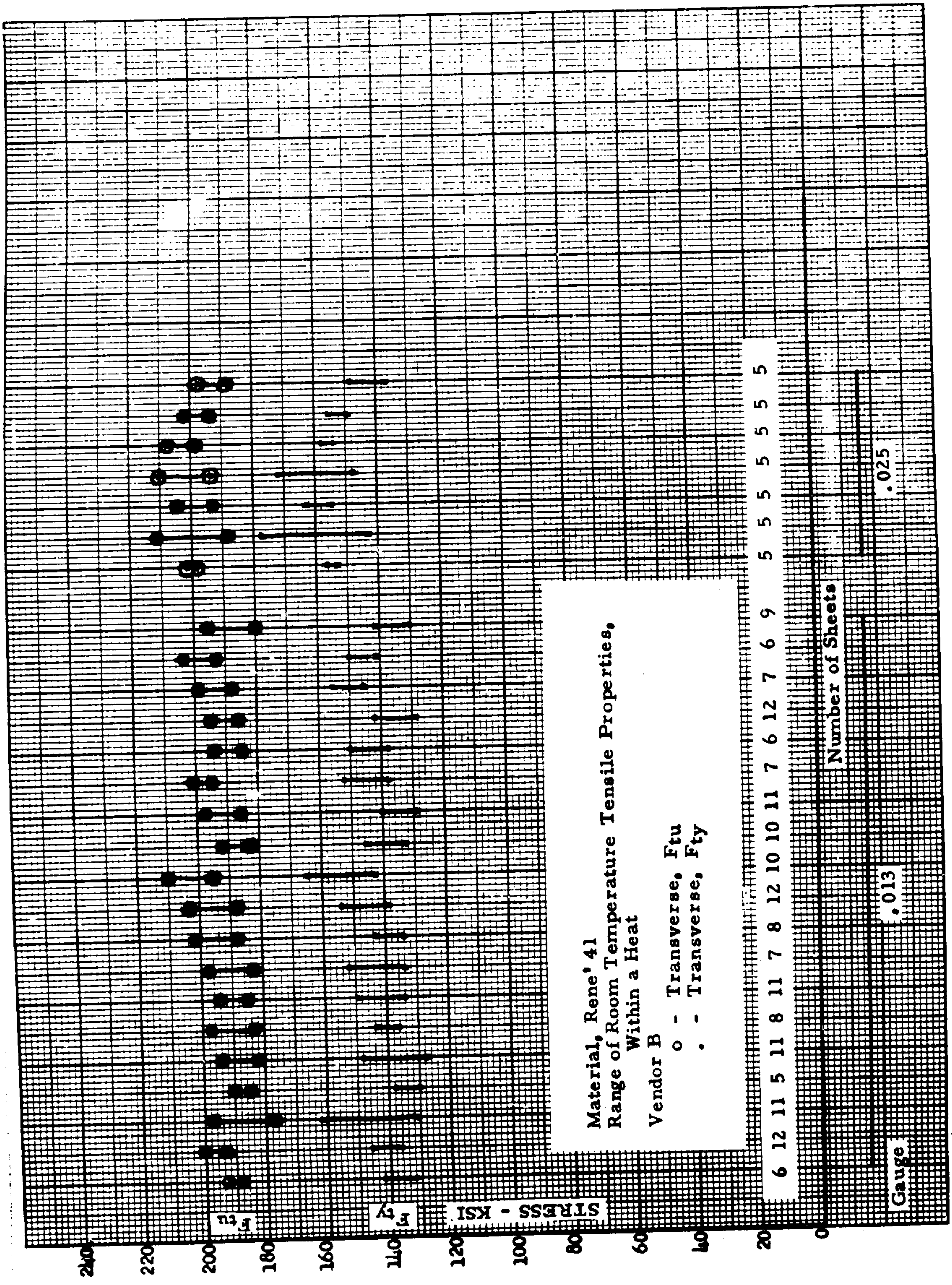

Material, Rene' 41
Range of Room Temperature Tensile Properties,
Within a Heat
Vendor B
o - Transverse, Ftu
. - Transverse, Fty
STRESS - KSI
Ftu
Fty
240
220
200
180
160
140
120
100
80
60
40
20
0
6 12 11 5 11 8 11 7 8 12 10 10 11 7 6 12 7 6 9 5 5 5 5 5 5 5
Number of Sheets
.013
.025
Gauge

FIG. 36

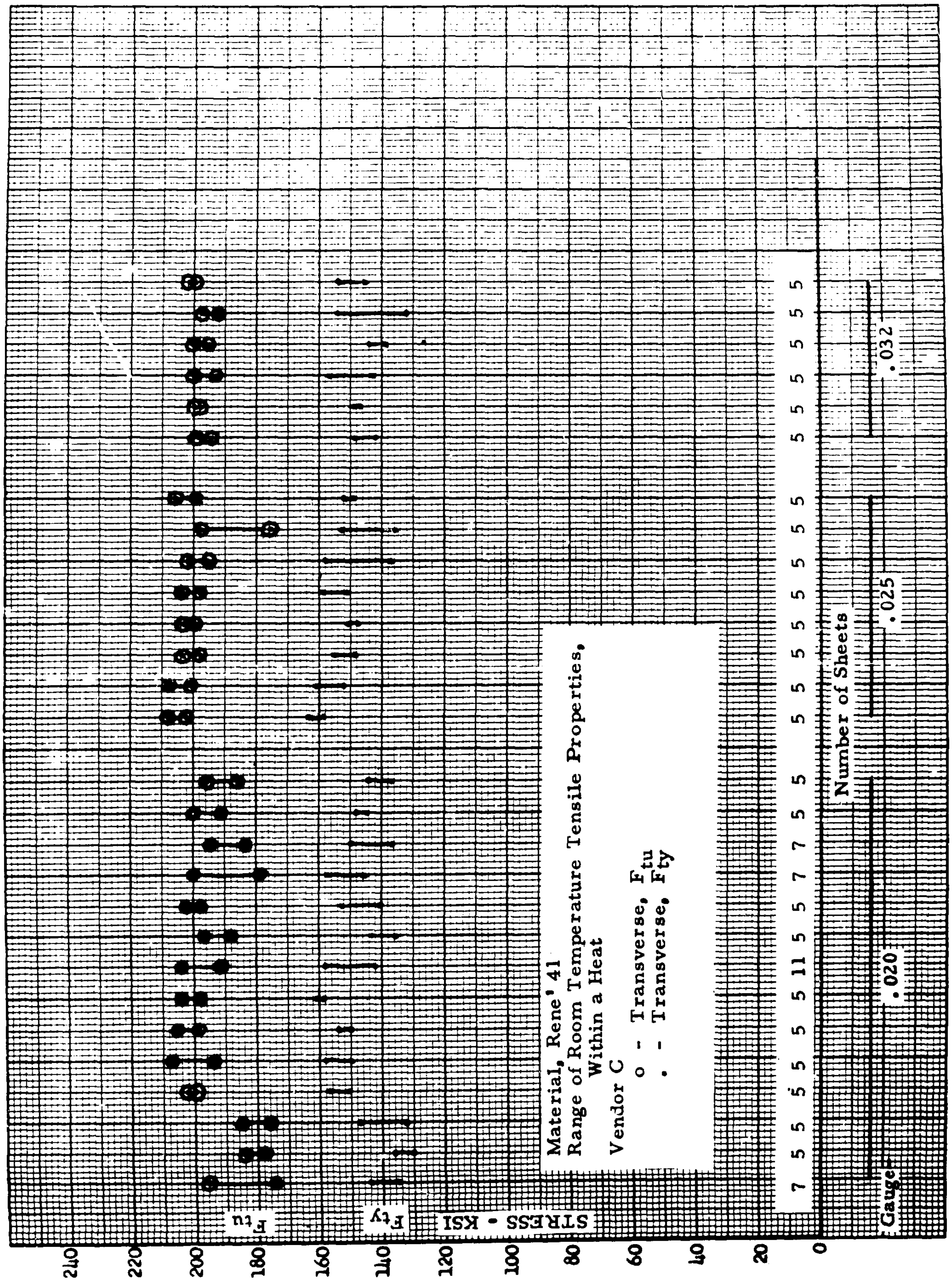
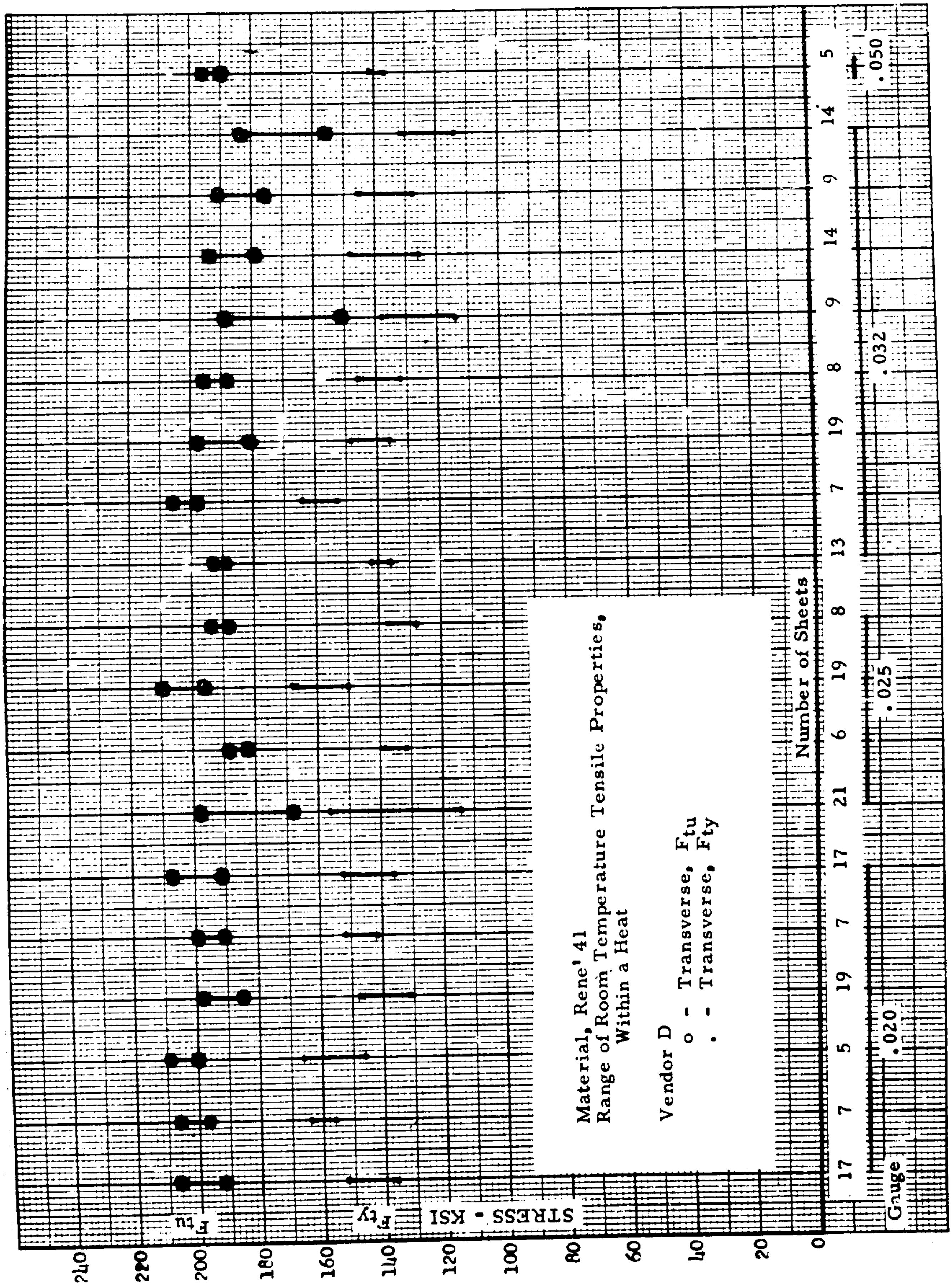

Material, Rene' 41
Range of Room Temperature Tensile Properties,
Within a Heat
Vendor C
o - Transverse, F_{tu}
. - Transverse, F_{ty}
STRESS - KSI
F_{tu}
F_{ty}
Number of Sheets
Gauge
.020
.025
.032

FIG. 37



Material, Rene' 41
Range of Room Temperature Tensile Properties,
Within a Heat
Vendor D
o - Transverse, F_{tu}
. - Transverse, F_{ty}
Number of Sheets
17 7 5 19 7 17 21 6 19 8 13 7 19 8 9 14 9 14 5
Gauge
.020
.025
.032
.050
STRESS - KSI
F_{tu}
F_{ty}
0 20 40 60 80 100 120 140 160 180 200 220 240

FIG. 38

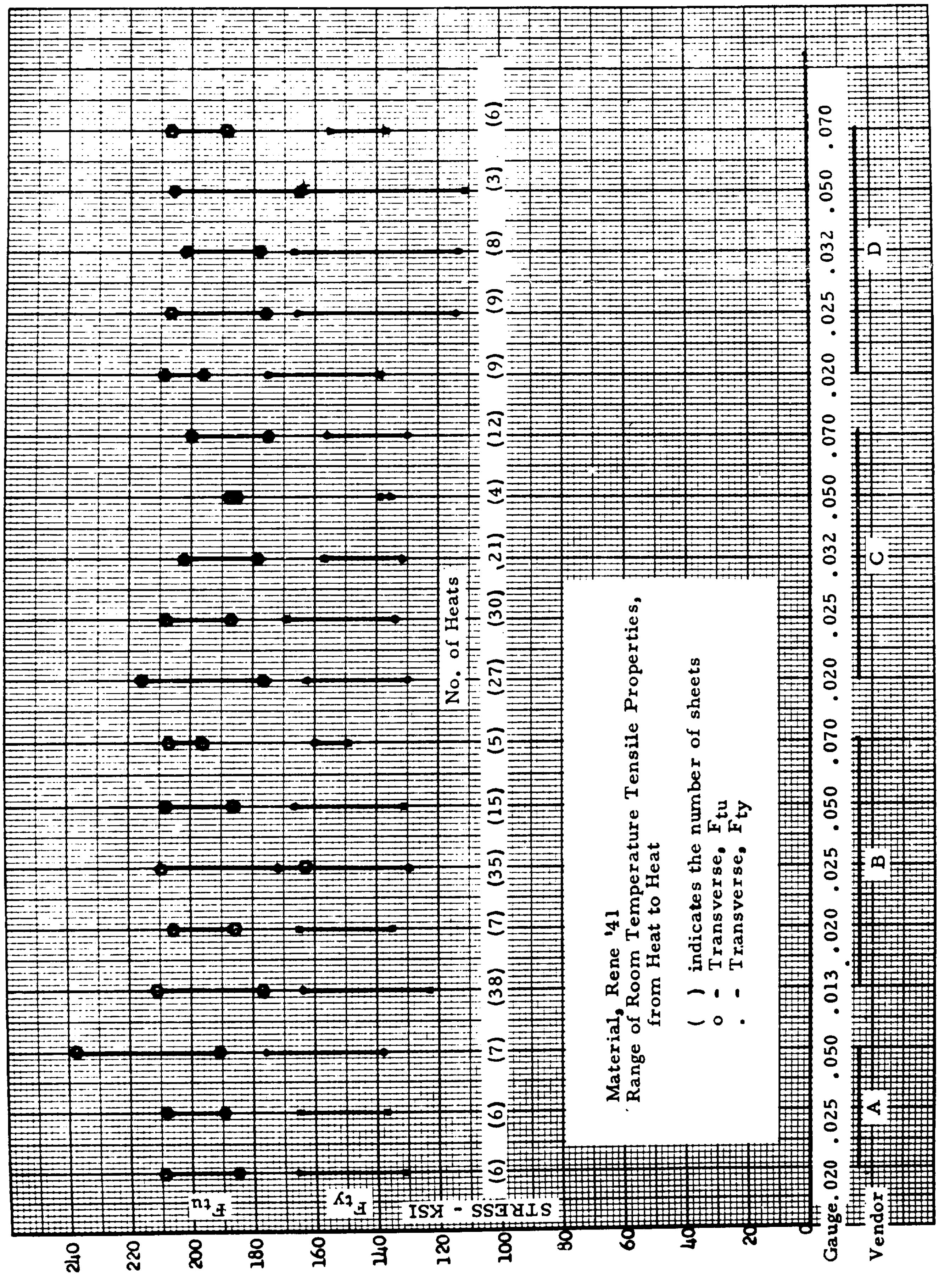

Material, Rene '41
Range of Room Temperature Tensile Properties, from Heat to Heat
( ) indicates the number of sheets
o - Transverse, F_{tu}
. - Transverse, F_{ty}
No. of Heats
(6) (6) (7) (38) (7) (35) (15) (5) (27) (30) (21) (4) (12) (9) (9) (8) (3) (6)
STRESS - KSI
F_{tu}
F_{ty}
0 20 40 60 80 100 120 140 160 180 200 220 240
Gauge .020 .025 .025 .050 .013 .020 .025 .050 .070 .020 .025 .032 .050 .070 .020 .025 .032 .050 .070
Vendor A B C D

FIG. 39

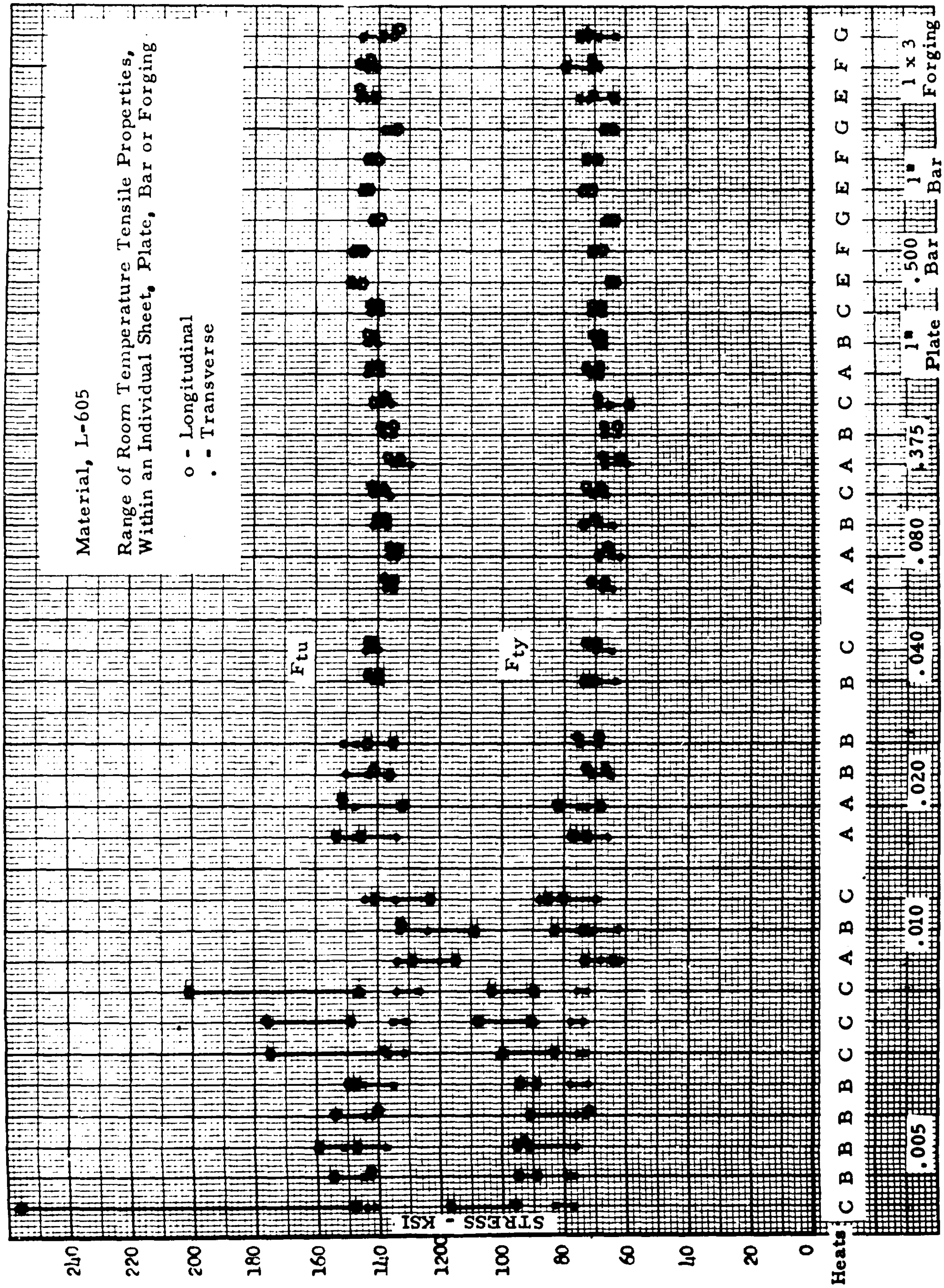
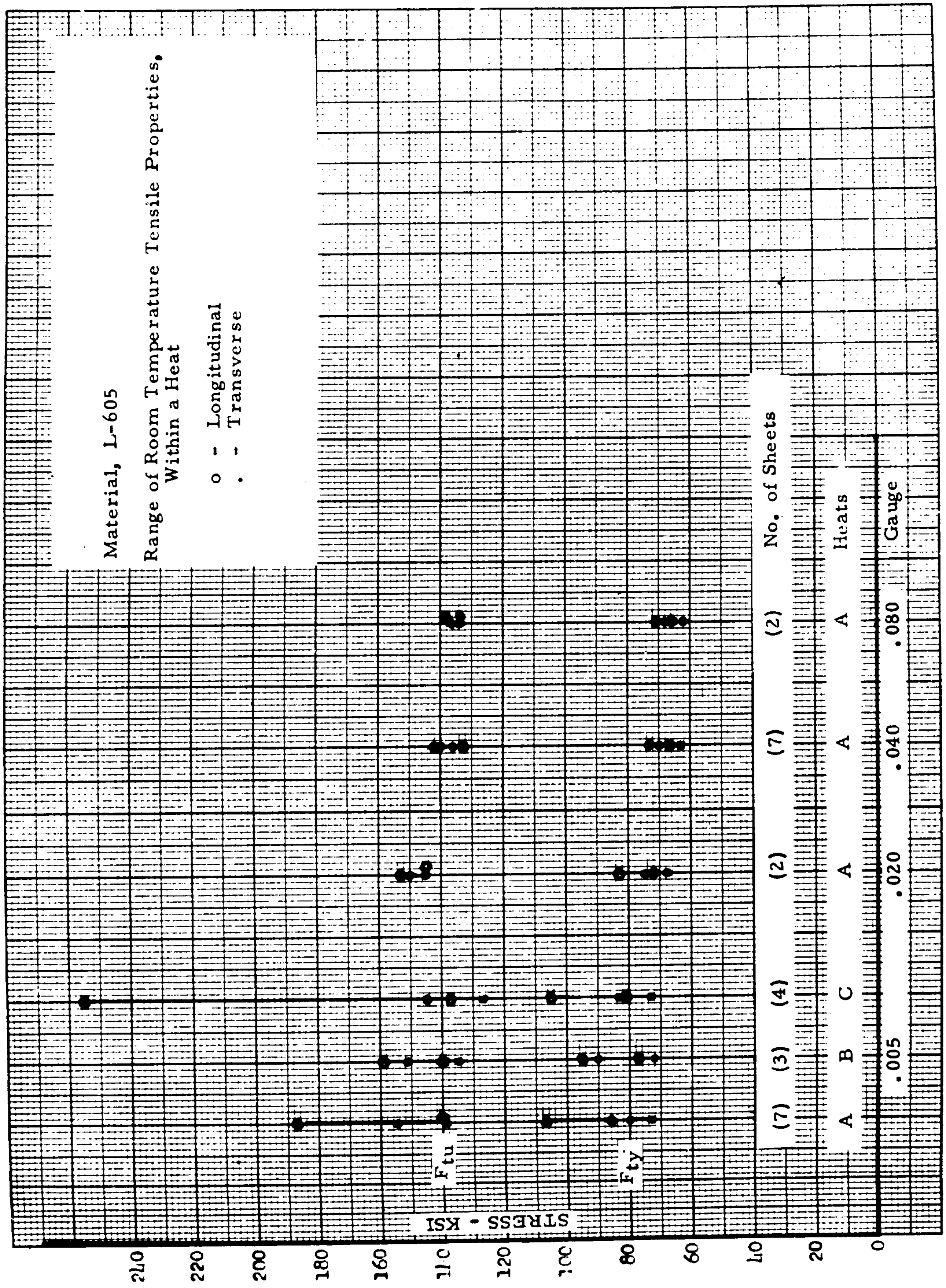
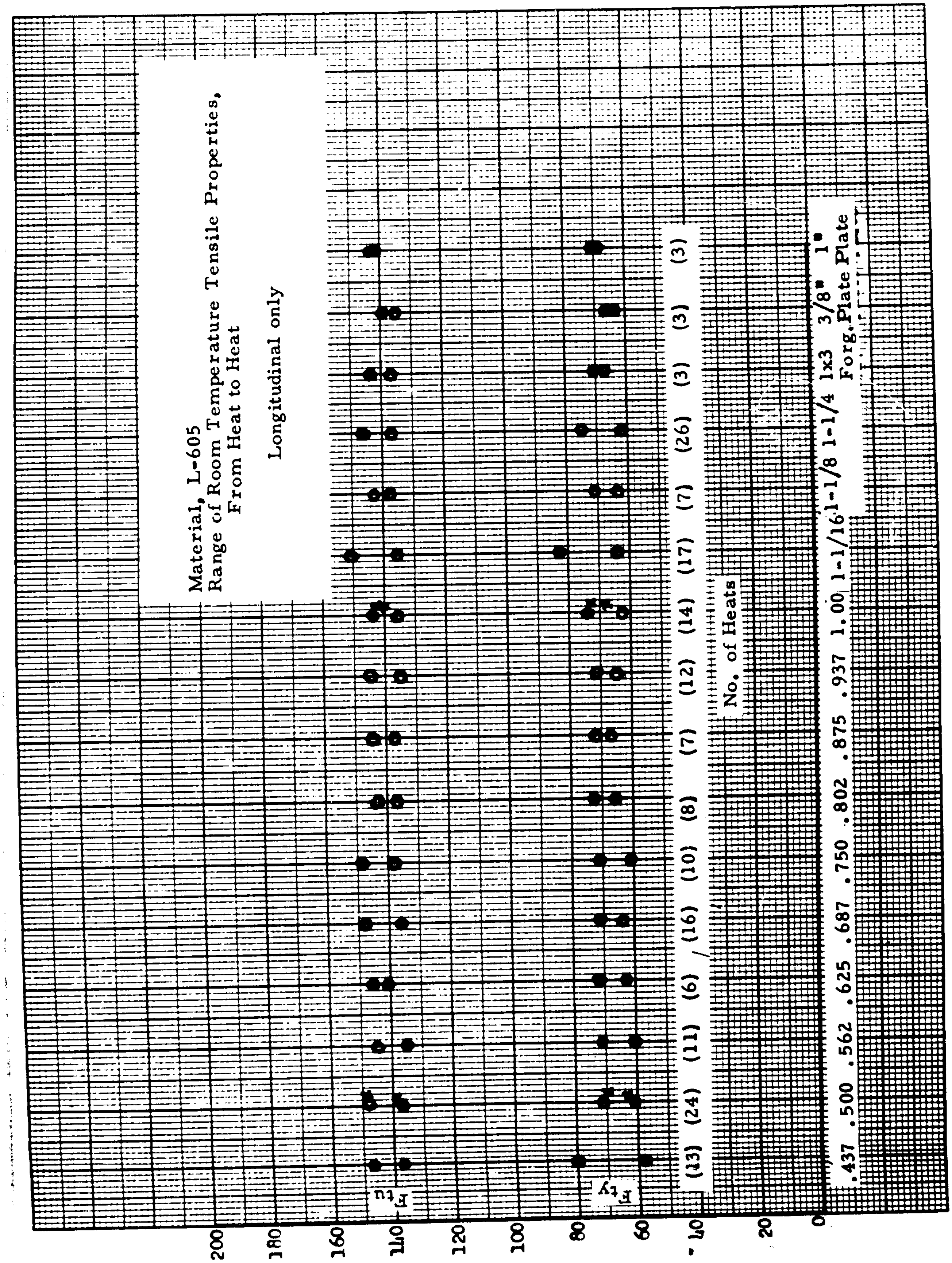

Material, L-605
Range of Room Temperature Tensile Properties, Within an Individual Sheet, Plate, Bar or Forging
o - Longitudinal
• - Transverse
Ftu
Fty
STRESS - KSI
240
220
200
180
160
140
120
100
80
60
40
20
0
Heats
C B B B B B C C C A B C A B C A A B B A A B B C A A B C A B C A B C E F G E F G E F G
.005
.010
.020
.040
.080
.375
1"
Plate
.500
Bar
1"
Bar
1 x 3
Forging

FIG. 40



Material, L-605
Range of Room Temperature Tensile Properties, Within a Heat
o - Longitudinal
. - Transverse
No. of Sheets
(7) (3) (4) (2) (7) (2)
Heats
A B C A A A
Gauge
.005 .020 .040 .080
Ftu
Fty
STRESS - KSI
0
20
40
60
80
100
120
140
160
180
200
220
240

FIG. 41



Material, L-605
Range of Room Temperature Tensile Properties,
From Heat to Heat
Longitudinal only
No. of Heats
(13) (24) (11) (6) (16) (10) (8) (7) (12) (14) (17) (7) (26) (3) (3) (3)
.437 .500 .562 .625 .687 .750 .802 .875 .937 1.00 1-1/16 1-1/8 1-1/4 1x3 3/8" 1"
Forg. Plate Plate
F_{tu}
F_{ty}
200
180
160
140
120
100
80
60
40
20
0

FIG. 42

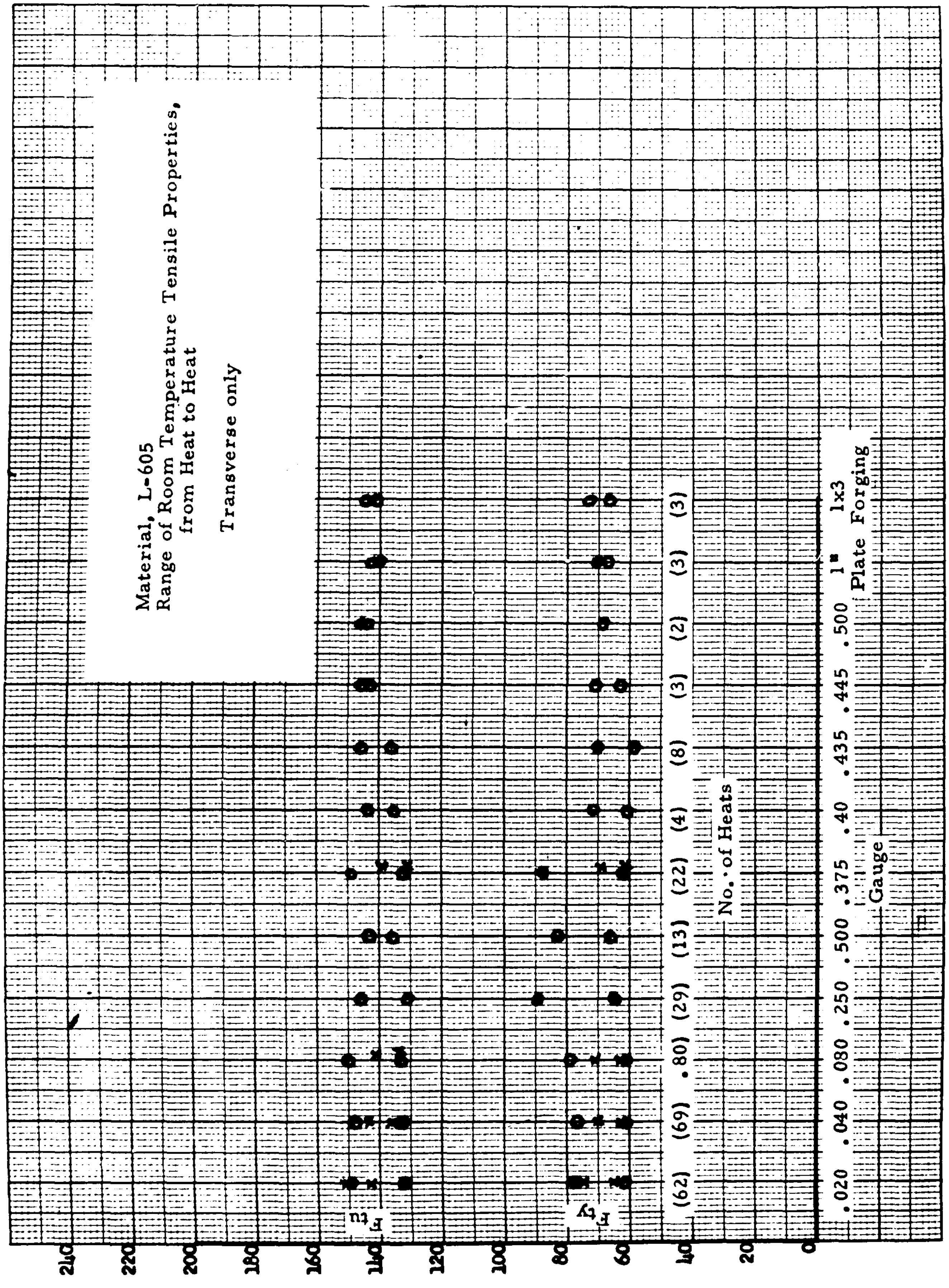
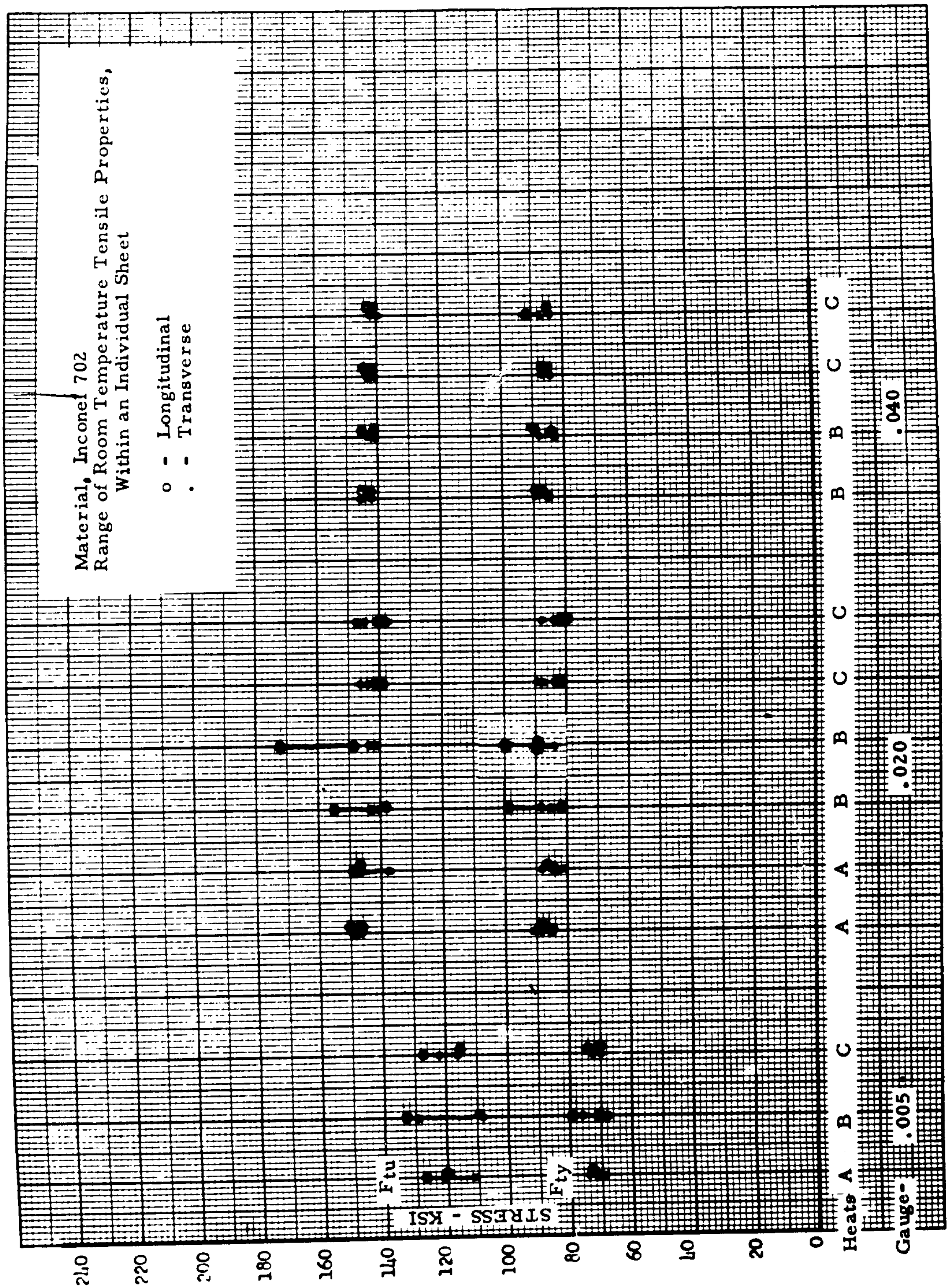

Material, L-605
Range of Room Temperature Tensile Properties,
from Heat to Heat
Transverse only
F_{tu}
F_{ty}
240
220
200
180
160
140
120
100
80
60
40
20
0
(62) (69) .80) (29) (13) (22) (4) (8) (3) (2) (3) (3)
No. of Heats
.020 .040 .080 .250 .500 .375 .40 .435 .445 .500 1" 1x3
Gauge
Plate Forging

FIG. 43



Material, Inconel 702
Range of Room Temperature Tensile Properties,
Within an Individual Sheet
o - Longitudinal
. - Transverse
STRESS - KSI
Ftu
Fty
240
220
200
180
160
140
120
100
80
60
40
20
0
Heats A B C A A B B C C B B C C
Gauge- .005 .020 .040

FIG. 44

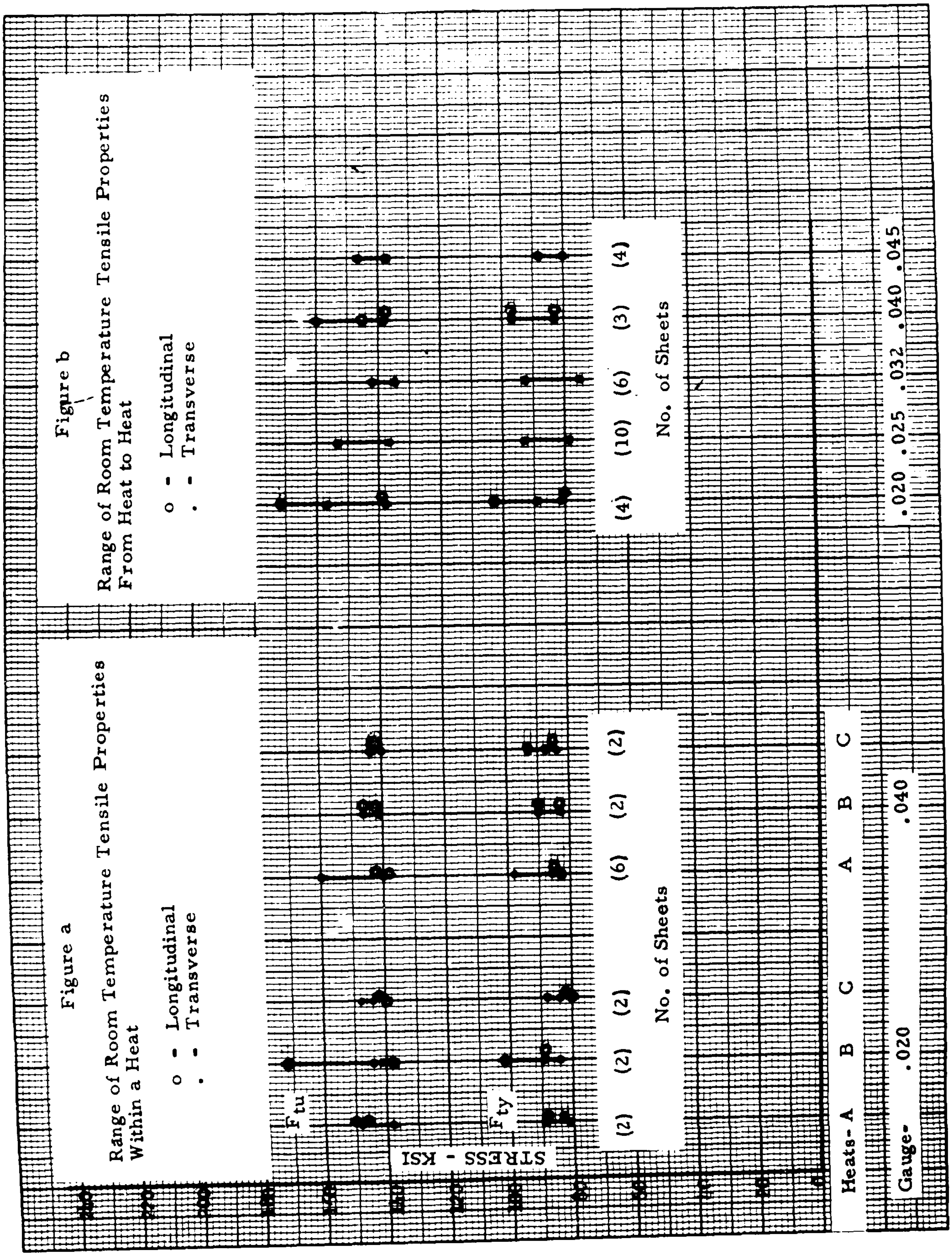


Figure a
Range of Room Temperature Tensile Properties Within a Heat
o - Longitudinal
. - Transverse
Figure b
Range of Room Temperature Tensile Properties From Heat to Heat
o - Longitudinal
. - Transverse
F_{tu}
F_{ty}
STRESS - KSI
(2) (2) (2) (6) (2) (2)
No. of Sheets
(4) (10) (6) (3) (4)
No. of Sheets
Heats- A B C A B C
Gauge- .020 .040
.020 .025 .032 .040 .045

FIG. 45

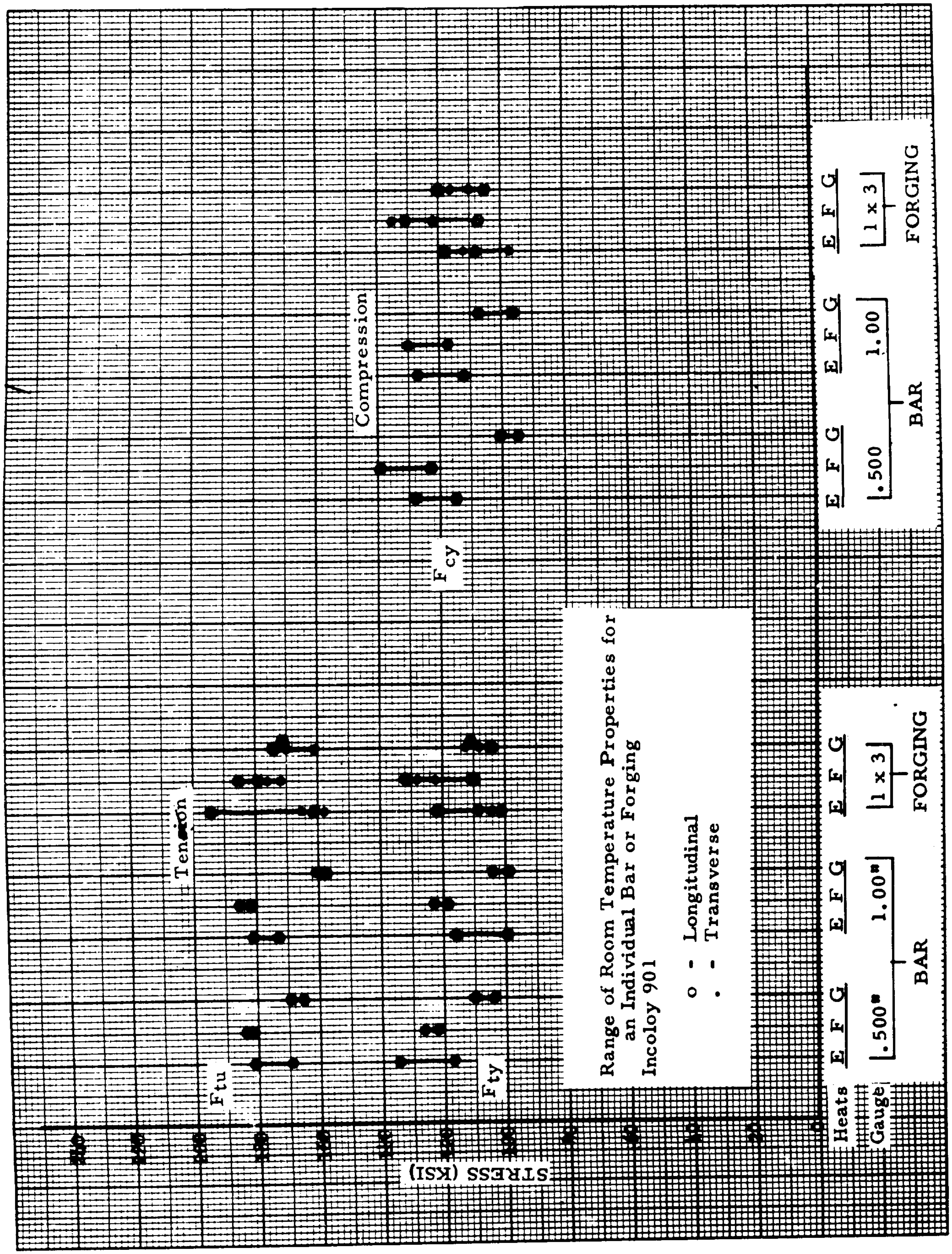

Range of Room Temperature Properties for
an Individual Bar or Forging
Incoloy 901
o - Longitudinal
. - Transverse
Tension
Ftu
Fty
Compression
Fcy
STRESS (KSI)
Heats
Gauge
E F G
E F G
E F G
E F G
E F G
E F G
.500"
1.00"
1 x 3
BAR
FORGING
E F G
E F G
E F G
E F G
E F G
E F G
.500
1.00
1 x 3
BAR
FORGING

FIG. 46

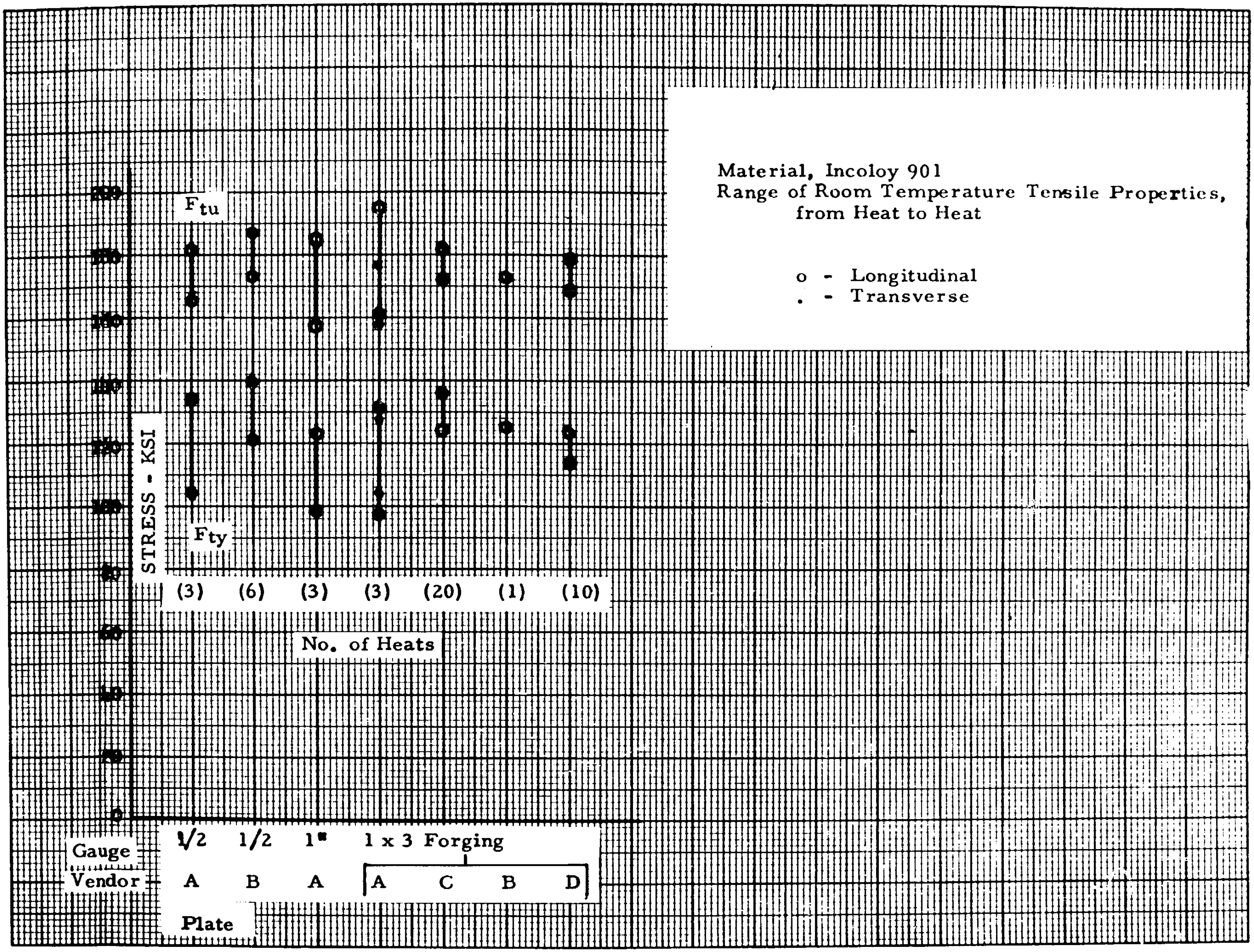

Material, Incoloy 901
Range of Room Temperature Tensile Properties, from Heat to Heat
o - Longitudinal
. - Transverse
F_{tu}
F_{ty}
STRESS - KSI
(3) (6) (3) (3) (20) (1) (10)
No. of Heats
Gauge
1/2 1/2 1" 1 x 3 Forging
Vendor
A B A A C B D
Plate

FIG. 47

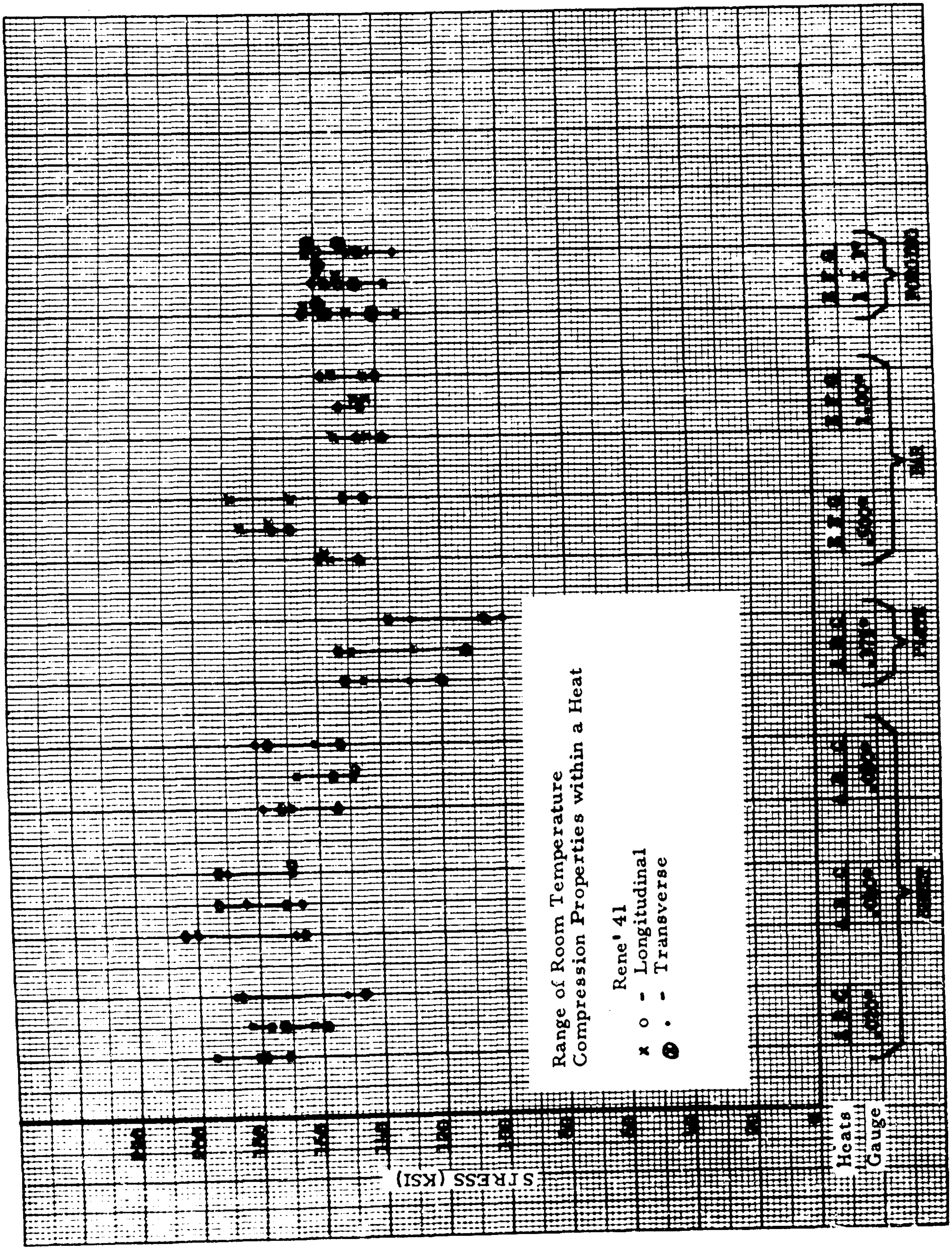
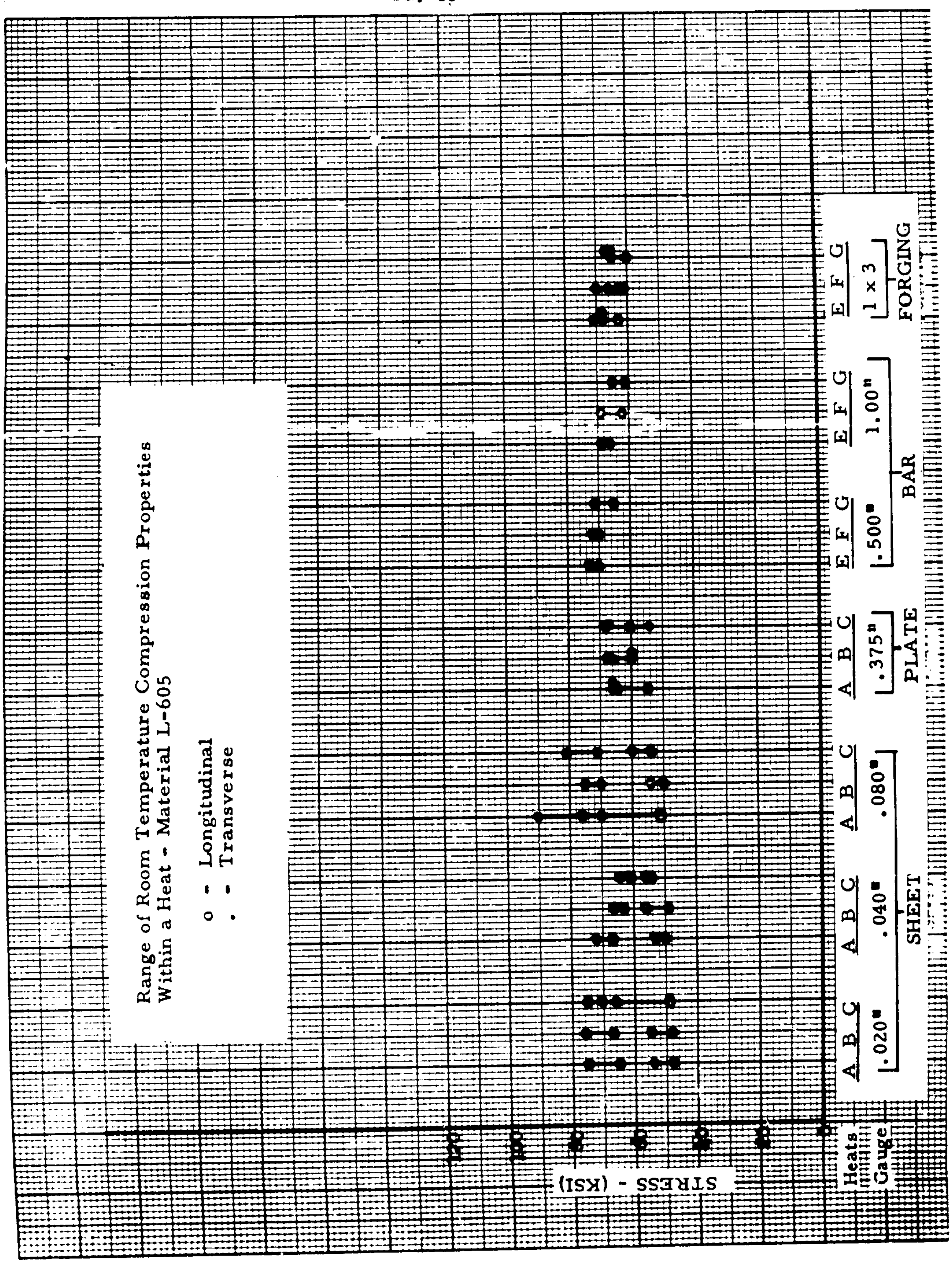
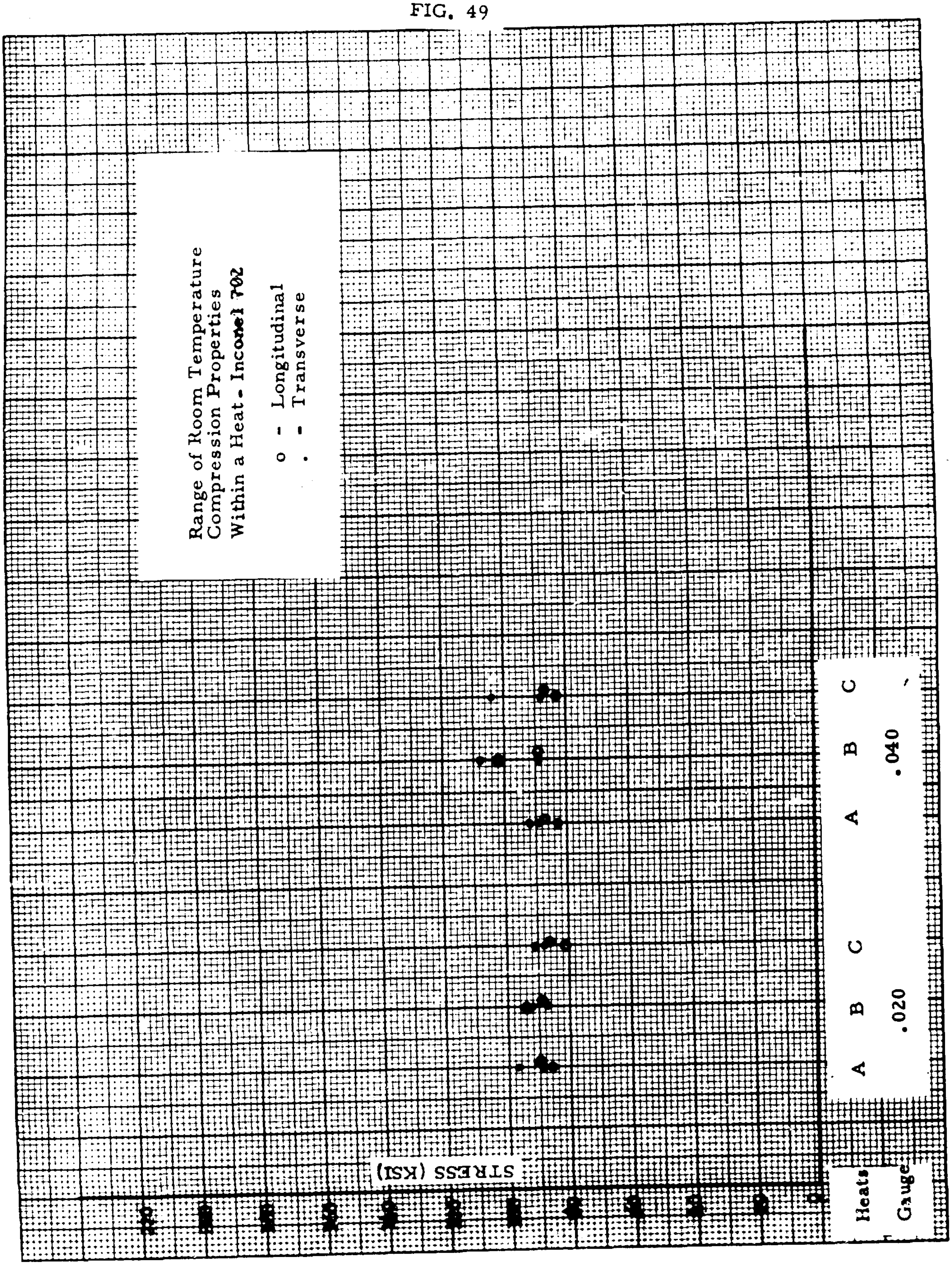

Range of Room Temperature
Compression Properties within a Heat
Rene' 41
x o - Longitudinal
• - Transverse
STRESS (KSI)
Heats
Gauge

FIG. 48



Range of Room Temperature Compression Properties
Within a Heat - Material L-605
o - Longitudinal
. - Transverse
STRESS - (KSI)
Heats
Gauge
A B C
.020"
A B C
.040"
A B C
.080"
SHEET
A B C
.375"
PLATE
E F G
.500"
E F G
1.00"
BAR
E F G
1 x 3
FORGING

FIG. 49



Range of Room Temperature
Compression Properties
Within a Heat - Inconel 702
o - Longitudinal
. - Transverse
STRESS (KSI)
Heats
A
B
C
A
B
C
Gauge
.020
.040

6.3.5 RANGE OF ROOM TEMPERATURE STRENGTH AND ELONGATIONS

TABLE NOs. 23 and 24

FIGURE NOs. 33 thru 49

TABLE 23

TENSILE STRENGTH AND ELONGATION OF SHEET MATERIAL RENE'41

VENDOR D MATERIAL

	Sheet #	Room Temperature 025" Gauge Ultimate KSI	Yield KSI	Elongation Percent	1400°F Ultimate KSI	Yield KSI	Elongation Percent
Heat X	1	190.6	156.9	24.9	174.2	-	12.5
	2	189.4	139.8	25.0	176.3	-	13.0
	3	184.0	136.2	24.5	163.8	-	14.0
	4	188.8	140.6	24.5	174.3	-	14
	5	190.2	139.8	23.0	177.0	-	14
	6	189.1	140.7	24.0	170.7	-	12.5
	7	194.6	143.9	24.0	168.9	-	13.5
	8	192.0	139.3	24.0	169.0	-	12.5
	9	189.9	137.4	26.0	171.4	-	14.5
	10	191.9	144.1	20.0	184.1	-	12.0
	11	195.5	149.8	23.0	174.0	-	13.0
	12	195.1	149.6	23.0	178.7	-	13.0
	13	198.0	156.0	22.0	192.2	-	10.5
	14	194.9	150.8	23.5	179.6	-	12.0
	15	193.7	145.1	23.5	185.1	-	12.0
	16	195.7	152.5	23.0	186.4	-	11.0
	17	195.2	151.0	22.5	168.8	-	12.0
	18	178.8	119.1	26.0	156.3	-	15.0
	18	183.0	121.4	24.0	-	-	-
	18	174.8	118.4	17.5	-	-	-
	19	178.3	125.3	27.0	159.8	-	14
	19	172.5	115.3	20.5	-	-	-
	19	174.1	118.7	23.5	-	-	-
	20	171.3	114.7	24.0	147.7	-	13.5
	20	169.1	114.5	20.0	-	-	-
	20	175.4	115.6	25.0	-	-	-
	21	177.6	117.6	22.5	161.0	-	14.5
	21	182.0	123.7	24.0	-	-	-
	21	189.9	140.7	23.5	-	-	-
AMS 5545 (min.)		170.0	130.0	10.0	135.0	-	3.0

Repetitive numbers indicate retests from same sheet.
All tests on this page come from the same Heat.

TABLE 23 (cont'd.)

TENSILE STRENGTH AND ELONGATION OF SHEET MATERIAL RENÉ 41

	Sheet #	Room Temperature 032" Gauge Ultimate KSI	Room Temperature 032" Gauge Yield KSI	Room Temperature 032" Gauge Elongation Percent	1400°F Ultimate KSI	1400°F Yield KSI	1400°F Elongation Percent
Heat Y	1	182	124.9	27.0	149	108.6	5.5
	2	189.1	137.8	23.5	146.7	121.1	11.5
	3	179.2	124.7	24.5	149.3	109.1	11.5
	4	172.7	122.1	19.5	143.7	107.9	11.5
	5	182.1	126.7	27.5	159.6	117.3	13.0
	6	175.6	119.9	27.5	158.7	112.7	14
	7	173.8	114.2	26.0	138	105.8	9
	7	178.8	121.6	18.0	-	-	-
	7	168.9	125.2	11.5	-	-	-
	8	176.8	124.4	21.5	141	104.5	9.5
	9	162.0	118.4	14.5	138	106.0	8
	9	162.0	118.4	14.5	-	-	-
	9	151.0	119.9	9.0	-	-	-
Heat Z	1	184	148.6	25.5	170.3	124.7	11.5
	2	193.5	148.2	22.5	157.3	121.2	11.0
	3	192.3	144.3	23.5	170	127	13
	4	194.6	140.6	23.5	147.2	121.5	8
	5	185.9	131.6	26.5	148.7	111.0	14
	6	188.5	142.5	22.0	160.5	121.3	16.5
	7	189.4	139.4	26.0	171.8	121.5	15
	8	186.9	132.4	26.0	166.0	122.0	15
	9	190.2	142.3	24.0	172.9	128.7	14
	10	188.3	132.7	24.5	173	119.9	16.5
	11	183.6	132.1	25.0	160.7	115.4	14
	12	192.7	139.3	26.0	181.4	129.1	14
	13	186.3	131.0	26.0	160.8	-	13
	14	180.2	126.2	27.5	168.9	125	15.5
	14	185.0	119.7	25.0	-	-	-
	14	178.9	124.7	21.0	-	-	-
	AMS 5545	170.0	130.0	10.0	140.0	110.0	3.0

Retests from same sheet.

Sheet groups 1-9 - Same Heat
Sheet groups 1-14 - Different Heat than 1-9

6.4 Mechanical Property Discussion, Material Rene' 41

Sheet

Effect of Temperature on Strength (Short Time)- Essentially there is no difference between the longitudinal and transverse properties except for the compressive yield strength where the transverse is higher to 1400°F at which point the curves join and remain the same to 1800°F. The compression yield is higher than the tension yield to 1400°F. There is only slight loss of strength for all properties up to 1200-1400 °F after which degradation becomes rapid. All the curves are nearly parallel to 1200°F.

Exposure Effects - Exposure at elevated temperature has no degrading effect on the room temperature properties with the exception of bearing strength below 1400°F; above this temperature deterioration is rapid even for the 10 hour curve. The bearing ultimate and yield show a secondary hardening effect and deterioration for long time exposure (500-1000 hours) starts at 1200°F.

Length of time at temperature has no effect on the elevated temperature properties below 1400°F; in comparison to the 1/2 hour condition; above this temperature, long time exposure does cause some additional degradation but it is not excessive.

Foil

Effect of Temperature on Strength (Short Time) - The curve for the ultimate tensile strength is parallel to that for sheet but consistently lower; the tensile yield strength is lower than for sheet to 1200°F where the curves join and only exhibit minor differences to 1800°F.

Exposure Effects - There is no effect of exposure at elevated temperatures on the room or elevated temperature strength below 1400°F; above this temperature deterioration is extremely rapid. When a time curve ends abruptly, it indicates that higher temperatures resulted in specimens which could not be tested due to severe degradation. Foil exposed was .005 inch.

Bar, Plate and Forging

Effect of Temperature on Strength (Short Time)- The sheet properties are generally higher to 1400°F where they tend to converge. The bearing and shear properties are almost identical with sheet. There is little loss of strength to 1400°F after which deterioration becomes rapid.

6.5 Material, L-605

L-605

The yield to ultimate strength ratio of this alloy in the solution treated condition is in the order of .45-.50. The alloy has very good ductility coupled with a high strain hardening rate. For this reason if the full ductility of which the alloy is capable is not achieved the full ultimate strength capability will not be developed. In the testing of the sheet and foil gauges this can create a real problem. Although the specimen is reduced by some .003 to .005 inches to force failure at the center of the reduced section the tremendous stretching that takes place over the whole gauge length causes the failure to be somewhat random over the entire test section. In addition the extensometer which bites into the material can be the deciding factor in inducing failure. All of these factors will tend to reduce ductility and ultimate tensile strength. The strain rate after yield may also influence the magnitude of the ultimate strength. The tests in this program were conducted in accordance with ARTC-12 which recommends .005 inch per inch per minute through the .2 per cent yield after which the rate is adjusted to induce failure in one minute. Since the percentage elongations in this alloy were as high as 60 per cent the strain rate to failure is abnormally high in comparison with most conventional materials.

These factors render the ultimate strength values somewhat questionable in many instances. This would not normally be an important factor in design since the low yield strength would be the determining factor in any analysis. If the data is being used to establish trends however, these factors should be considered.

Sheet

Effect of Temperature on Strength (Short Time) - There is no difference in the longitudinal and transverse properties throughout the temperature range investigated, except for the compressive yield strength (Fcy). The transverse compressive yield strength is higher than the longitudinal at room temperature, the curves tend to converge join at approximately 1400°F and are the same out to 1800°F.

The compressive yield (Fcy) and tensile yield (Fty) strengths are almost identical. The tensile and compressive yield strengths (Fty and Fcy) show very good retention of properties after an initial drop, (between room temperature and 800°F) out to 1800°F.

The tensile and shear ultimate strengths (Ftu and Fsu) are approximately parallel to about 1300°F, after which they converge meeting at 1800°F. The bearing ultimate strengths (Fbru) for e/D = 1.5 and e/D = 2.0 are approximately parallel to each other and to the tensile ultimate (Ftu). The bearing yield strengths (Fbry) for e/D = 1.5 and e/D = 2.0 are approximately parallel to each other and to the tensile yield Fty) up to 1400°F after which the bearing strength tends to fall off at a higher rate.

Exposure Effects - Exposure at elevated temperatures shows no significant loss in room temperature strength except for the ultimate tensile (Ftu) which exhibits a slight decrease for long exposures (500-1000 hours) in the 1600-1800°F range. This loss in tensile strength is attributed to a decrease in ductility. All other properties show a secondary hardening effect.

The curves illustrating the effect of exposure time on the elevated temperature strengths show all curves higher than the 1/2 hour curve except the 1000 hour curve which shows some slight degradation for temperatures in excess of 1400°F.

Plate, Bar and Forging

Effect of Temperature on Strength (Short Time) - There is no difference between longitudinal and transverse properties. The ultimate tensile strength is almost the same as for sheet to 1000°F then becomes higher. The tensile yield strength is slightly lower for bar, plate and forging, then for sheet over the whole temperature range to 1700°F where they join. The compressive yield strength is almost identical to the tensile yield strength. The shear ultimate is lower than that of sheet until approximately 1150°F where they cross, then is higher to 1800°F where they join.

The bearing ultimate stress with e/D = 2.0 starts out lower than for sheet but crosses the sheet curve at 900°F and is higher to 1800°F. The bearing yield strength with e/D = 2.0 is lower than for sheet over the entire temperature range. The bearing ultimate strength with e/D = 1.5 is lower than sheet over the entire temperature range while the yield strength with e/D = 1.5 starts higher than for sheet but crosses at 550°F and remains lower.

Foil

The longitudinal and transverse tensile yield strengths (Fty) of .010 inch foil are identical.

The transverse tensile yield strength (Fty) of the .005 inch foil is slightly lower than the longitudinal over the whole temperature range investigated. The .005 inch foil has higher tensile ultimate (Ftu) and yield (Fty) strengths than the .010 inch foil.

The tensile yield strength (Fty) of sheet lies between the .005 inch foil and .010 inch foil over the whole temperature range.

Exposure Effects - All exposure data were obtained on .005 inch foil. There is no effect of exposure at elevated temperatures or the room temperature strengths below 900°F; above this temperature deterioration is rapid even after 10 hours.

exposure for the ultimate tensile strength (Ftu), while the yield strength (Fty) shows a secondary hardening effect at 1200°F and deterioration starting at 1400°F for 10 - 500 hours and at 1200°F for 1000 hours. Specimens exposed for 1000 hours at 1800°F could not be tested because of the warpage and general material degradation due to oxidation.

The effect of time at temperature on the elevated temperature tensile ultimate shows deterioration starting as low as 1100°F for long time exposures. The tensile yield curves in this category show secondary hardening at 1200°F and the start of degradation at about 1400°F for the longer exposure times.

6.6 Mechanical Property Discussion, Materials Inconel 702 and Incoloy 901

6.6.1 Material Inconel 702

Sheet

Effect of Temperature on Strength (Short Time) - The longitudinal and transverse properties are the same throughout the temperature range investigated. The difference between the ultimate tensile (Ftu) and the tensile yield (Fty) strengths is large from room temperature to 800°F. Above 800°F, the ultimate strength (Ftu) starts deteriorating rapidly while the yield strength (Fty) starts to rise slightly at 1000°F, peaks at 1200°F and then falls off rapidly. From 1400 to 1800 °F, the tensile ultimate (Ftu) and tensile yield (Fty) strengths are almost identical (the ultimate, Ftu, being slightly higher). The same effect (i.e., overlapping of ultimate and yield) is displayed in the bearing strength (Fbru and Fbry) for both edge distances (i.e., e/D = 1.5 and e/D = 2.0). The bearing yield strengths (Fbry) do not show the secondary hardening effect (i.e., rise of curve at 1000°F) seen in the tensile yield (Fty).

The shear ultimate strength (Fsu) runs out almost parallel to the ultimate tensile strength (Ftu) until 1200°F, then declines less rapidly and the curve crossing at approximately 1550°F.

The compressive yield strength (Fcy) is equal to the tensile yield strength from room temperature to 400°F, then starts to rise, peaks at 1000°F and then deteriorates rapidly meeting the tensile yield (Fty) at 1300°F and remaining equal to it out to 1800°F.

The curves (Fbru) are approximately parallel to the ultimate tensile (Ftu) curve. The shape of the bearing yield strength (Fbry) curves are almost the same as the tensile yield curve (Fty); they do not however display the secondary hardening effect.

Exposure Effects - For exposure times up to 1000 hours there is no degradation of room temperature strength properties for exposure temperatures below 1000°F. The curves for all the properties indicate a secondary hardening effect in the temperature range 800-1000 °F. In the 1200-1800 °F range the room temperature tensile ultimate and yield (Ftu and Fty) and the compressive yield (Fcy) strengths show an initial decline in properties which occurs within a ten hour period and subsequent exposure does not result in additional deterioration; in some cases, the longer exposure results in higher room temperature strengths. The room temperature bearing ultimate (Fbru) and yield (Fbry) and the shear ultimate (Fsu) strength curves do show increasing degradation with increasing exposure time in the 1400-1800 °F.

All the curves indicate that the greatest degradation occurs at approximately 1600°F, after which the curves tend to flatten out.

There is very little effect of exposure time on the elevated temperature strengths of this material. In all cases the 1/2 hour and 1000 hour curves are almost identical. Significant differences only appear at temperatures above 1200°F and always disappear by 1800°F.

Foil

Effect of Temperature on Strengths (Short Time)- There is little degradation of the ultimate tensile strength (Ftu) below 1000°F; above this point decay is rapid. The decline of the tensile yield strength (Fty) is slow below 1000°F, the rate of decay increases above this temperature but not as rapidly as the ultimate strength. The ultimate and yield strengths (Ftu and Fty) of the foil are lower than the sheet until approximately 1600°F where they tend to converge.

Exposure Effects - There is no effect of exposure at elevated temperature on the room temperature ultimate tensile (Ftu) or tensile yield (Fty) strengths below 1200°F. Above this temperature the rate of degradation increases with increasing exposure time. The foil does not display the secondary hardening effect seen in the sheet. Length of exposure at elevated temperatures has little effect on the elevated temperature tensile yield strength (Fty); the 1/2 hour and 1000 hour curves being almost identical with a maximum difference of approximately 16 per cent at 1400°F. Length of time at temperature has a greater effect on the elevated temperature ultimate tensile strength (Ftu); rapid degradation begins at a lower temperature and the maximum difference is approximately 30 per cent at 1300°F. This latter condition is accompanied by a loss in ductility probably due to oxidation effects.

6.6.2 Material Incoloy 901

Effect of Temperature on Strength (Short Time) - The longitudinal tensile ultimate strength (Ftu) is slightly higher than the transverse up to 1400°F where they converge. This is also true in the case of the tensile yield (Fty), compressive yield (Fcy) and shear ultimate (Fsu), except that the compressive yields do not join until a slightly higher temperature (1500°F). The retention of strength of this alloy is good, showing only slight losses in strength up to 1000-1200°F range.

Exposure Effects - Exposure for periods of time up to 100 hours have no effect on the room temperature ultimate tensile strength for temperatures below 1400°F; above this temperature, deterioration is rapid. For longer exposures (i.e., 500-1000 hours) deterioration begins at 1000°F and progresses rapidly. Exposure effects on the room temperature tensile yield strength are approximately the same as for the ultimate strength except that deterioration begins at a somewhat lower temperature (1200°F) for 10-100 hour exposure. Above 1600°F there is little effect of length of exposure on these properties. Only .005 inch foil was tested.

Exposure for periods up to 100 hours have no effect on the elevated temperature properties at temperatures below 1200°F; above this temperature the deterioration in comparison to the 1/2 hour curve reaches a maximum at 1400°F to 1500°F after which the 1/2 hour and 100 hour curves start to converge. For exposures of 500-1000 hours, the deterioration of elevated temperature strengths starts at 1000°F with the maximum degradation in comparison with the 1/2 hour curve occurring at 1400°F for the ultimate and 1200°F for the yield. Above 1600°F there is little effect due to length of time of exposure.

6.7 Creep

Creep tests were conducted for the materials - Rene '41, L-605, Inconel 702, and Incoloy 901. The tests were performed at temperatures of 1200, 1400, 1600, and 1800 °F for time periods up to 1000 hours. The various forms for each alloy are shown on the respective graphs in Section VII. The graphs plotted indicate the stress versus the time in hours for a family of percentages of plastic deformations ranging from 0.05 up to 1.0 per cent. The curves normally shown as a single family have been separated in many instances due to overlapping of test points and data scatter in order to more clearly observe the difference (if any) due to section thickness or material form. Where test points are not shown for the drawn curves, the test results had been obtained with little scatter.

6.7.1 Rene' 41

The total plastic deformation curves at 1200°F (Figures 81, 88, 89) are closely grouped and diverge for the longer time periods for all forms except the 0.005 inch gauge foil. This latter data is shown as plotted points only due to data scatter. At 1400°F, (Figures 90 - 92), the curves are uniformly diverging as the time periods increase with the thinner sections dropping more rapidly. The data for the foil gauge is shown to have more scatter at the lower percentage deformations. At 1600°F, (Figures 93 to 95, 99, 100) the curves are more widely separated due to section thickness and longer time periods indicating an accumulative effect of time-temperature oxidation. The tendency for curve reversal at the longer time periods is noted since the slope again tends to approach that stress rupture curve. Similiar trends are noted at 1800°F (Figures 96 through 100) with the exception of the forgings curve. The basic tensile strength of the forging material had considerable variation within the forging as well as lower strength than the 0.5 inch diameter bar. However, as time-temperature oxidation effects increased, the forging material maintained a higher percentage of its initial strength, thereby crossing over the curves for the thinner gauge material as shown on the respective graphs.

6.7.2 L-605

The resulting curves for the total plastic deformations for the material L-605 are shown in Figures 188 to 198 for the various temperatures. At 1200°F, separate curves are shown for the 0.005 inch gauge foil and the 0.040 inch gauge sheet. The data resulted in fairly consistent curves with the curves for foil falling slightly below the curves for 0.040 inch sheet.

The plotted results shown at 1400°F are relatively closely grouped for the various forms with consistent results shown for the .005 inch gauge foil except at the 0.05 per cent deformation for which no curve was drawn for the foil gauge due to scatter of test results. At the 0.05 per cent deformation and the 0.1 per cent deformation the time periods range from up to 20 hours and 50 hours respectively for the sheet material and up to 650 hours for forgings.

At $1600^{\circ}F$ a single series of composite curves for all forms are plotted at the higher deformation (1.0 and 0.5 per cent), and are noted to be parallel to the stress-rupture curve for the 0.5 inch bar. At the lower deformations, the curve for foil is consistent but separated from the curve shown for all other forms.

The curves shown for data at $1800^{\circ}F$ are near parallel to stress-rupture curves up to 100 hours then widely diverge as a function of section thickness with foil data being limited to 100 hours in most cases.

6.7.3 Inconel 702

The plastic deformation curve for Inconel 702 as shown in Figure 272 for sheet material only. At the $1200^{\circ}F$ temperature, curves are drawn for the 0.040 inch gauge sheet for all deformations with a few points shown for the .005 inch gauge foil at the lower deformations. The $1400^{\circ}F$ temperature curves develop slight reversals of curvature after relatively short time periods before continuing on parallel to the stress-rupture curve. Data for the 1.0 per cent deformation curve was not recorded since rupture occurred near the 1 per cent deformation point. The material evidently approached third stage creep deforming rapidly, shortly after the previous data had been recorded.

At $1600^{\circ}F$ and $1800^{\circ}F$ the curves are drawn as straight lines with the .05, 0.1 and 0.3 per cent deformation curves having a single break in slope occurring at time periods less than 100 hours. For each per cent deformation, a single curve is plotted as a composite of the three sheet gauges.

6.7.4 Incoloy 901

The test results for total plastic deformation of Incoloy 901 are plotted and shown in Figure 314 to Figure 319 . At the $1200^{\circ}F$ temperature, only data for 0.500 inch bar is plotted for all deformations and is noted to be straight lines, closely spaced and parallel to the stress-rupture curve up to 1000 hours. Data for both bar and forgings are shown at $1400^{\circ}F$ temperature, the curves having a gentle decreasing slope at the center sections before dropping more rapidly at longer time periods. The curves are consistent for the whole family of deformations. At $1600^{\circ}F$ temperature, however the data for 0.500 inch bar is almost straight and parallel to the stress-rupture curve for the 0.3, 0.5 and 1.0 per cent deformations, while a significant drop off occurs at approximately 50 hours before leveling off at the longer time periods over 100 hours.

At the $1800^{\circ}F$ temperature, data for 0.500 inch bar and forging material is very consistent and composite curves are drawn for each of the respective deformations and are very similar in pattern. The time periods range from 200 hours for the 0.05 per cent deformation curve to beyond 1000 hours for the 1.0 per cent deformation curve.

6.8 Stress Rupture

The stress rupture evaluation accumulate data for all alloys over the 1200 to 1800 $^{\circ}$F range in 200°F increments. Individual families of curves are given for each material form or gauge, and in some cases, for each grain direction.

The form or gauge of each alloy that had been subjected to maximum testing was used for computation of a best fit Larson Miller constant and master rupture curve. The remaining forms or gauges of a specific alloy were then examined for conformance with the parametric plot for the 'standard'.

Material forms selected as base data are as follows:

Rene' 41	0.040 inch sheet, transverse
L-605	0.040 inch sheet, transverse
Inconel 702	0.040 inch sheet, transverse
Incoloy 901	0.5 inch bar

Where a significant departure was observed for a different form or gauge, an additional curve was incorporated on the master rupture plot. This base data was first qualified with available published information. No major discrepancies were observed between the data generated in this investigation and average values obtained in a literature search.

Unfortunately, very little foil rupture data was available for supplementary information. As a consequence, foil properties were not included in master rupture plots. The behavior of this gauge was always lower in rupture life and sometimes erratic in behavior.

6.8.1 Rene' 41

Stress rupture data obtained for Rene' 41 proved extremely uniform within a given form. Stress to rupture curves presented in Figures 103 through 107 indicate identical performance for all sheet gauges (with the exception of foil) regardless of grain orientation. The same is true of bar and forged materials, Figure 108 through 110 . However, substantially higher rupture lives were exhibited by this class of material beyond 1400°F. A progressive increase in life is observed at 1600 and 1800°F over sheet with increasing time and temperature. This is assumed to be a result of oxidation since the short time elevated temperature strengths for both classes of material are essentially equal and the plots for each at a given temperature are markedly divergent rather than parallel.

The master rupture chart, Figure 102 for sheet and bar illustrates this by convergence of the two curves with decreasing values of parameter.

Foil testing indicated greatly reduced performance compared to sheet. Curves have been plotted only to 100 hours life in consideration of the relatively small quantity of data generated and the severe oxidation observed in thermal exposure specimens for times beyond this amount. See Figure 101.

6.8.2 L-605

The L-605 stress rupture plots over the 1200 to 1800 °F range are provided in Figure 199 through 208. No major variation was found to exist within a given material form.

Bar and forging properties are generally superior to sheet material particularly at the longer times and higher temperatures where loss of area through oxidation is most pronounced. Oxidation effects, however, are not as great as was observed when comparing Rene' 41 sheet and bar, and only become appreciable at 1800°F for extended times.

A Larsen-Miller parametric constant of 19 was employed to produce the master rupture chart of Figure 102. Foil (.005 inch) was not included in the master plot because of limited data available. Examination of the stress to rupture curves for this gauge reveal generally lower performance than heavier sheet material. Some difficulty was experienced at 1200°F resulting in questionable data points higher in life than for sheet. Stress rupture curves for foil have only been plotted to lives of 100-300 hours, the level of reasonable confidence.

6.8.3 Inconel 702

Stress rupture plots for Inconel 702 are given in Figure 274 through 278.

Larsen-Miller representation of data obtained for 0.040 inch sheet (transverse) resulted in a constant of 25 being most suitable. The balance of material, with the exception of 0.005 inch foil, exhibited good conformance with the basic plot.

Foil gauge testing indicated severe divergence throughout the 1200 to 1400 °F range. Data for 1600 and 1800 °F approximates that generated for heavier gauge sheet.

6.8.4 Incoloy 901

Stress rupture testing of Incoloy 901 evolved the curves shown in Figure 320 through 323. Rupture lives for 0.5 and 1.0 inch bar, and 1 x 3 inch forged bar were found to be equivalent.

The Larsen-Miller curve developed for the 0.5 inch bar resulted in a constant of 29 as being most suitable.

6.9 Axial Fatigue Data

Axial fatigue data was accumulated for all materials evaluated in this program. Table 11 provides an outline of the testing format for each alloy form.

All data has been presented as individual S/N plots for a specific form, stress ratio and temperature. A survey of available literature produced nothing in the way of supporting data to confirm or extend these fatigue diagrams.

In attempting to satisfy the low cycle fatigue requirements (10^2 - 10^4 cycles) of the investigation, a large number of tests were performed at maximum stresses well above the 0.2 per cent yield stress of the material at temperature. As a consequence, severe plastic deformation and attendant work hardening were encountered. The resultant strengthening and the effects of temporary preload changes occurring with specimen deformation are indeterminate in nature; resulting in data of questionable validity. This situation was ultimately corrected by limiting the maximum stress to values lower than yield strength. Unfortunately the change was made rather late in the program when a significant percentage of tests had already been completed.

The 0.2 per cent yield strength is indicated on each S/N plot by a dashed line. This yield strength represents the rated or design curve value generated from tensile tests performed during the course of this investigation.

The stress ratio 'A' being equal to the alternating stress/mean stress by reading the graphs for maximum stresses; the other pertinent stresses are determined as follows:

$$\text{Mean stress} = \frac{\text{Maximum stress}}{1 + A}$$

$$\text{Alternating stress} = \text{Maximum stress} \times \frac{A}{1 + A}$$

$$\text{Minimum stress} = \text{Maximum stress} \times \frac{1 - A}{1 + A}$$

6.9.1 Rene' 41

An axial fatigue evaluation was conducted on Rene' 41 in two sheet gauges, 0.040 and 0.080 inches, and 1.0 inch diameter bar. Stress ratios from A = 0.25 to A =0.98 were employed up to 1800 F.

6.9.1.1 0.040 Inch Sheet Transverse

a. Stress Ratio A=0.25 (Figures 111 to 120)

The largest number of tests at room temperature were conducted above the rated (design curve value) 0.2 per cent yield strength. However, a valid endurance limit below yield was obtained at 135 ksi. Subsequent testing from 600 to 1200 $^{\circ}$F considered only a single load level under yield strength at temperature. All tests produced run-outs beyond 10^6 cycles at a stress level equal to the 10^7 endurance limit at room temperature.

A substantial reduction in fatigue life was found at 1400 $^{\circ}$F, coincidental with the fall-off in static strength and ductility.

No detrimental effects were apparent with increased cycling rate at 1000, 1200, and 1400 $^{\circ}$F.

b. Stress Ratio A=0.67 (Figures 121 to 129)

A format identical to that of A = 0.25 was followed for this stress ratio in that only part of the ambient temperature testing was performed below the rated 0.2 per cent yield stress.

Heavy scatter was encountered within 1200 to 1400 $^{\circ}$F minimum ductility range. Beyond 10^5 cycles tests from 400 to 1200 $^{\circ}$F produced fatigue lives equaling or exceeding room temperature performance.

c. Stress Ratio A=0.98 (Figure 130 to 134)

A room temperature endurance limit (10^7 cycles) was obtained at 80 ksi. Data taken at 600 and 1000 $^{\circ}$F tended to approximate the room temperature curve over the entire life range. At 1000 $^{\circ}$F wide scatter was evident but resulted in an endurance limit of the same order as room temperature. Maximum scatter was again produced at 1400 $^{\circ}$F.

6.9.1.2 0.080 Inch Sheet Transverse

a. Stress Ratio A=0.25 (Figure 135 to 138)

The room temperature S/N curve effectively duplicates that of 0.040 inch sheet with an endurance limit of approximately 140 ksi. Data obtained for elevated temperatures were ambiguous due to the use of maximum stresses well above the rate 0.2 per cent yield strength.

b. Stress Ratio A=0.67 (Figure 139 to 142)

Room temperature S/N data produced for 0.080 inch gauge material provides a reasonable approximation to the lighter gauge material previously evaluated. Elevated temperature S/N data were evolved on a composite of test results run above and below the rated 0.2 per cent yield strength.

6.9.1.3 One Inch Bar

a. Stress Ratio A=0.67 (Figure 143 to 147)

Testing of one-inch diameter bar at A=0.67 was conducted for the most part at maximum stresses above the 0.2 per cent yield strss. Some useful data was obtained in the vicinity of 10^8 cycles for temperatures of 800, 1200, and 1600 °F.

b. Stress Ratio A= ∞ (Figure 148)

Only ambient temperature data to 10^6 cycles was produced for this ratio. When attempting tests at 1000 and 1600 °F, extreme scatter was encountered at all load levels. Further evaluation at elevated temperatures was not attempted.

6.9.2 L-605

An axial fatigue program was conducted on L-605 in 0.040 and 0.080 inch sheet (transverse specimen orientation) and on 1.0 inch diameter bar.

A large percentage of testing was performed at maximum stresses above the 0.2 per cent yield strength. The extremely low proportional limit of this alloy in the solution treated condition made load selection to obtain low cycle data difficult. The high ductility and notch toughness of this material permits a 10^7 cycle run-out at ambient temperature with stresses slightly below the 0.2 per cent yield strength, for example, .040 gauge sheet at room temperature, the stress ratio (alt. stress/mean stress), A = 0.98.

6.9.2.1 0.040 Inch Sheet (Transverse)

a. Stress Ratio A=0.25 (Figure 209 to 217)

Ambient temperature S/N data was taken entirely above the material yield strength. Failures were induced over the 10^2 to 10^7 range. Elevated temperature requirements at 600 - 1200 °F to establish a 10^6 cycle run-out were satisfied with maximum stresses just below the rated (design curve value) yield strength. At 1400 °F, the maximum stress had to be reduced an additional amount below yield to obtain consistent run-out at 10^6 cycles.

Increased cycling speed (1800 versus 3600 cpm) at 1000, 1200, and 1400 °F produced no reduction in fatigue life.

b. Stress Ratio A=0.67 (Figure 220 to 228)

Room temperature S/N data for this stress ratio was obtained with a minimum of tests because of incorrect loads applied throught part of the testing. All tests represent maximum stresses above the 0.2 per cent yield strength.

Elevated temperature fatigue performance was obtained from 400 to 1800 °F in 200 °F increments. Maximum stresses for all tests were held below the yield strength. Stress to cause run-out at 10^6

cycles (minimum) were determined for all temperatures except 1800°F.

c. Stress Ratio A=0.98 (Figure 233 to 237)

The bulk of specimens at ambient temperature were again run above the rated (design curve value) yield strength. Some data was obtained below yield establishing a 10^7 cycle run-out. Tests performed at 600, 1000, 1400, and 1800 °F yielded valid 10^6 cycle lives.

6.9.2.2 0.080 Inch Sheet Transverse

a. Stress Ratio A=0.25 (Figure 218, 219)

All tests were performed above the rated 0.2 per cent yield strength. Therefore, a comparison with 0.040 inch sheet material was not possible.

b. Stress Ratio A=0.67 (Figure 229, 230)

Both ambient and elevated temperature tests with the exception of 1600°F were conducted above the rated 0.2 per cent yield strength. Elevated temperature testing employed only a single load level for a given temperature, primarily to establish correlation with 0.040 inch gauge material. Actually, due to the excessive maximum stresses applied, a check with .040 inch material was only possible at 1600°F, where 0.080 inch sheet demonstrated higher fatigue life.

6.9.2.3 One Inch Bar A=.67 (Figures 231, 232)

a. All tests for ambient and elevated temperature were run above the rated 0.2 per cent yield strength. S/N data at seven stress levels was obtained at ambient temperature and at 2-4 stress levels at elevated temperatures.

6.9.3 Inconel 702

Inconel 702 was examined at 3 stress ratios (A=0.25, 0.67, and 0.98) over the room temperature to 1800°F range. Transverse specimens in 0.040 inch sheet were used exclusively.

a. Stress Ratio A=0.25 (Figure 279 to 287)

An ambient temperature endurance limit (10^7 cycles) was obtained at 85 ksi. S/N data was produced only for this temperature. The 85 ksi value represents the 0.2 per cent yield strength, hence all data on this plot were obtained after some degree of plastic deformation of the specimen.

Elevated temperature properties were checked at a single load level in most instances. This load was intended to be a practical maximum held just below the 0.2 per cent yield strength. At temperatures of 600, 1000, 1200 and 1800 °F, no failures were encountered at 10^6 cycles. These tests were subsequently discontinued.

At 1400°F an equivalent value of stress produced failure at 10^5 cycles, possibly a result of minimum ductility inherent to the alloy at this temperature. A corresponding reduced life was observed in creep testing where deformations greater than 0.9 per cent could not be obtained before rupture. The majority of creep specimens failed in the 0.3-0.5 per cent deformation range.

The effect of cycling rate, 1800 versus 3600 CPM, was included in the 702 testing although not originally scheduled. Testing at 3600 CPM was conducted at 1000, 1200, and 1400 °F. Comparative data at 1000° and 1200° are inconclusive since the stress levels selected for the higher cycling rate were excessively low, necessitating discontinuance of tests without failure between 10^6 and 10^7 cycles. At 1400°F where failure occurred at each of 2 stress levels, the 3600 CPM rate seemed to exert only a minor reduction in fatigue life.

b. Stress Ratio A=0.67 (Figures 288 to 296)

The room temperature S/N data was taken both above and below 0.2 per cent yield strength. A 10^7 cycle endurance limit was obtained at 6' ksi.

Elevated temperature tests were performed from 400 to 1800 °F in increments of 200°. Depending on a specific temperature, data was produced for maximum stresses both higher and lower than rated 0.2 per cent yield strength at temperature.

c. Stress Ratio A=0.98 (Figures 297 to 301)

As in testing at A=0.67, loads equaling or exceeding yield strength at temperature were employed for a large portion of the testing. A room temperature endurance limit (10^7 cycles) of 58 ksi was indicated.

6.9.4 Incoloy 901

Incoloy 901 was evaluated in the form of 1.0 inch diameter bar stock of appropriate intervals between ambient temperature and 1800°F. Stress ratios of A=0.67, 0.98, 2.0 and were examined.

The majority of data generated for the 901 alloy was not influenced by work hardening effects incurred by applying maximum stresses above yield strength.

a. Stress Ratio A=0.67 (Figures 324 to 334)

Considerable overlap is evident in testing within the 400-1200 °F range. Data for these temperatures reveal slightly superior performance over the room temperature plot, understandable in view of the constant

yield strength and increasing ductility up to 1200°F.

The first obvious reduction in fatigue life was observed at 1400°F at the low cycle end of the plot. At 10^7 cycles, the maximum stress was equivalent to that of room temperature. Tests at 1200 and 1400 °F with increased cycling rate (3600 CPM) resulted in insignificant changes in fatigue life.

b. Stress Ratio A=0.98 (Figures 335 to 339)

The family of curves developed at A=0.98 closely resemble those of A=0.67. Data overlap occurred to 1000°F with the first substantial drop in life taking place at the low cycle end of the 1400°F curve. At 10^6 cycles all data from ambient to 1400°F tends to merge to what is apparently a common endurance limit at 10^7 cycles.

c. Stress Ratio A=2.0 (Figures 340 to 344)

A minimum of data overlap was found in testing at A=2.0. S/N curves plotted for ambient, 600, 1000, 1400 and 1800 °F show fairly clear separation, particularly at low and intermediate cycle ranges. At 10^6 cycles, the data again tended to converge. A clear picture of performance was not obtained since tests were not conducted beyond 10^6 cycles.

d. Stress Ratio A=∞ (Figures 345 to 349)

The S/N curves developed for A=∞ fell into the same temperature relationship as found for A=2.0 possessing good low cycle separation and convergence at 10^6 cycles. A room temperature endurance limit was defined at 47 ksi.

SECTION VII - TEST RESULTS, TABLES AND GRAPHS

SECTION 7.1 MATERIAL, RENE' 41

TABLE OF CONTENTS

SECTION VII

SECTION 7.1.1 TENSION

FIG. 50

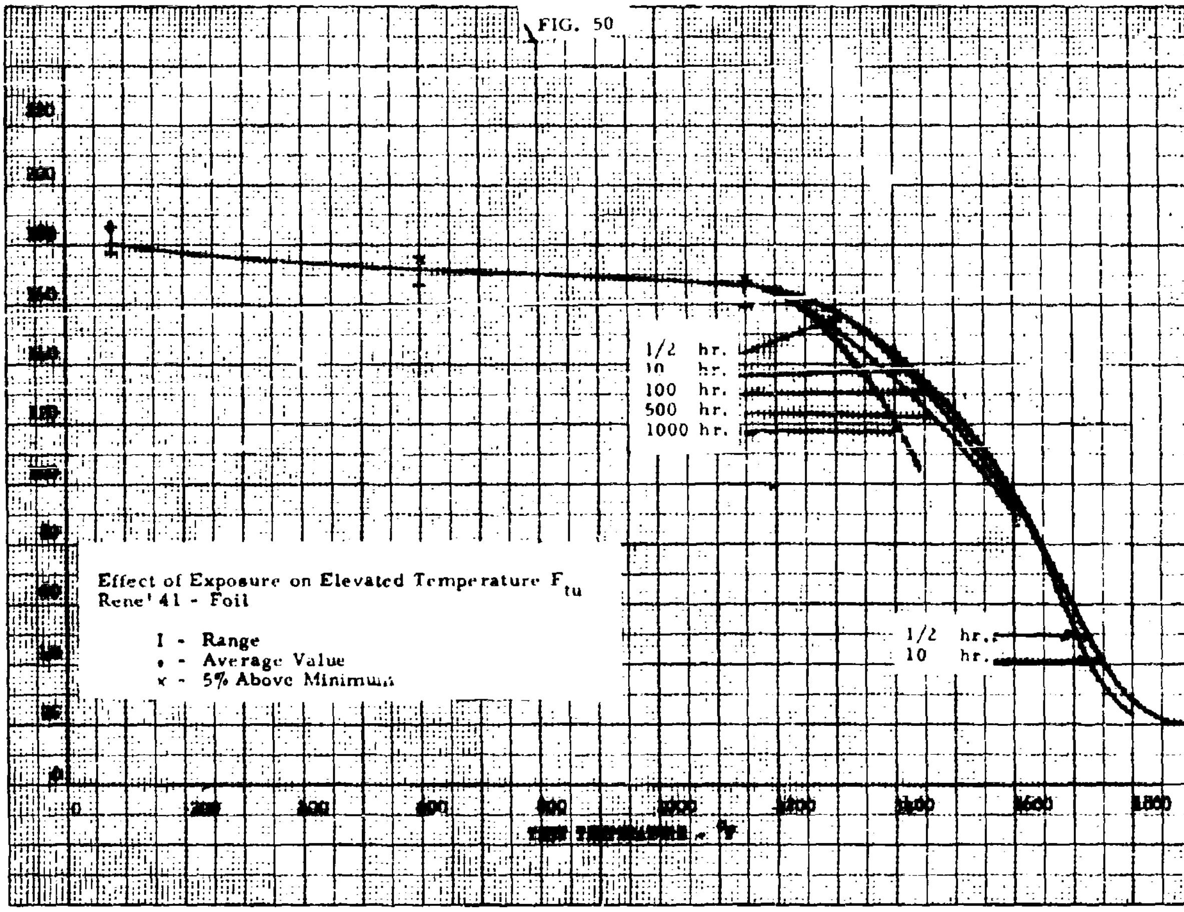

Effect of Exposure on Elevated Temperature F_{tu}
Rene' 41 - Foil
I - Range
• - Average Value
x - 5% Above Minimum
1/2 hr.
10 hr.
100 hr.
500 hr.
1000 hr.
F_{tu} - KSI

FIG. 51

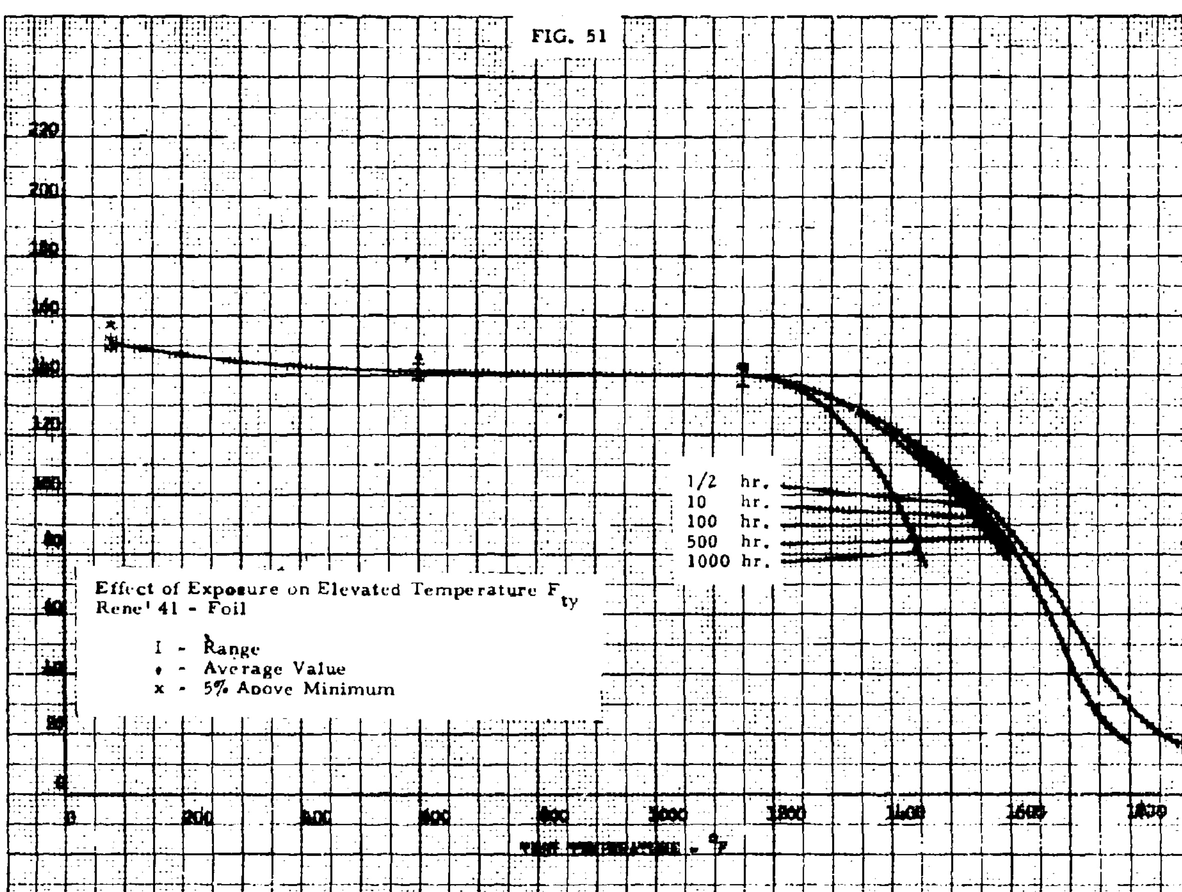

Effect of Exposure on Elevated Temperature F_{ty}
Rene' 41 - Foil
I - Range
• - Average Value
x - 5% Above Minimum
1/2 hr.
10 hr.
100 hr.
500 hr.
1000 hr.
F_{ty} - KSI
220
200
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 52

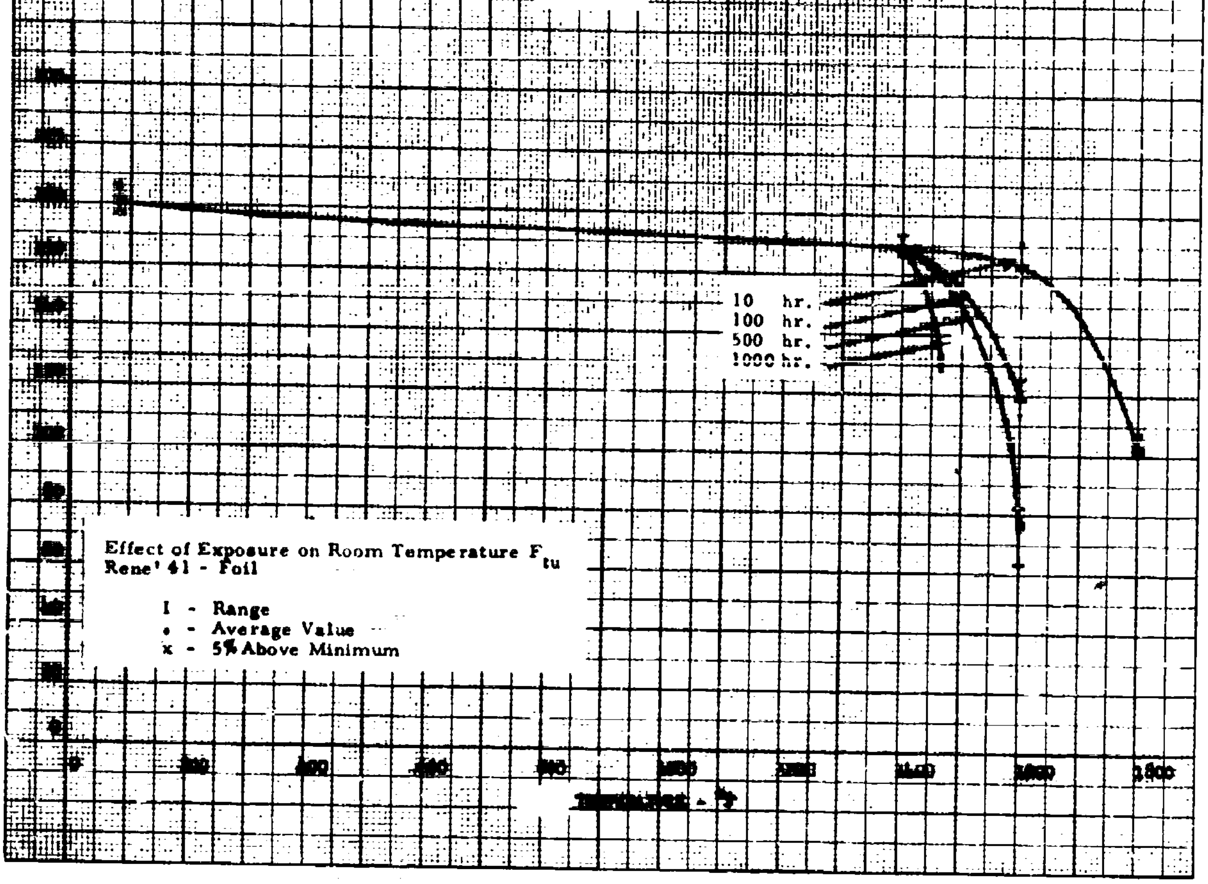
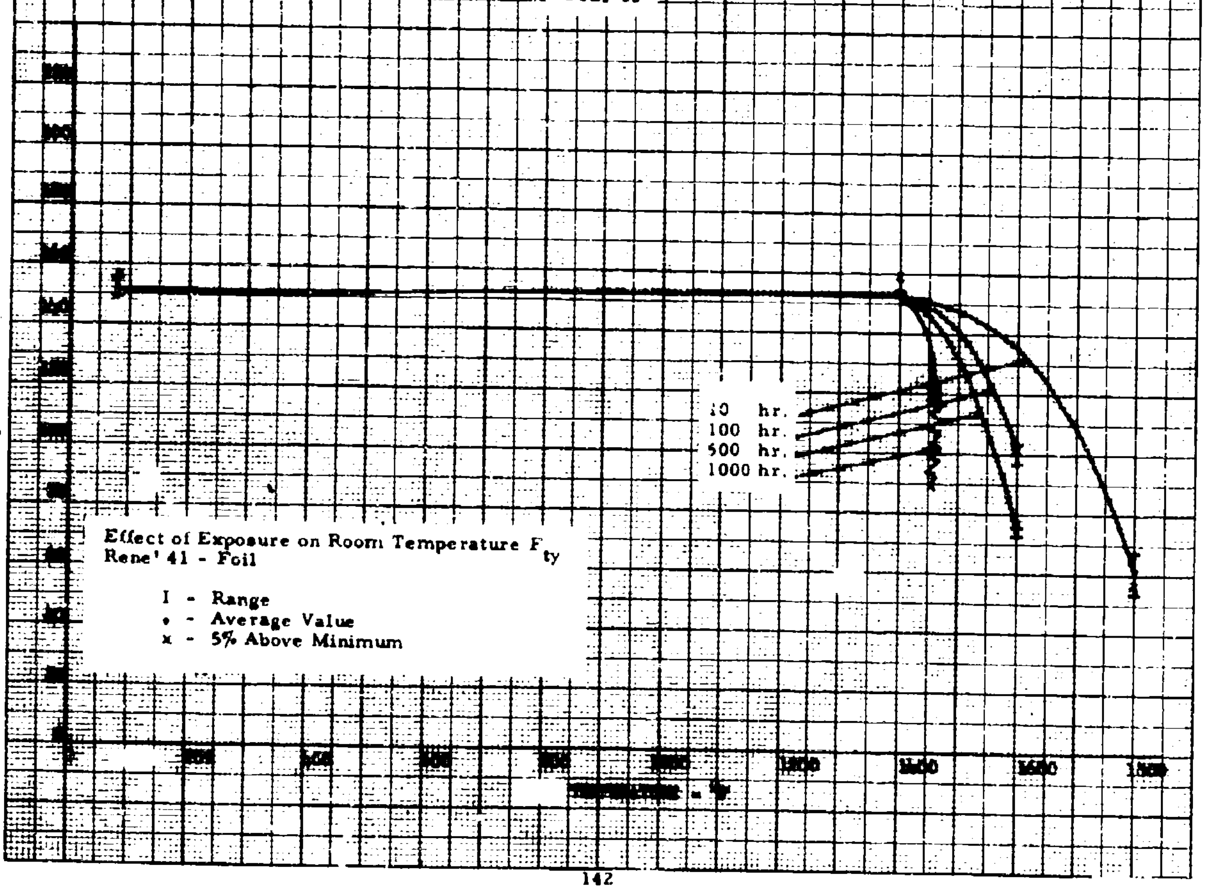
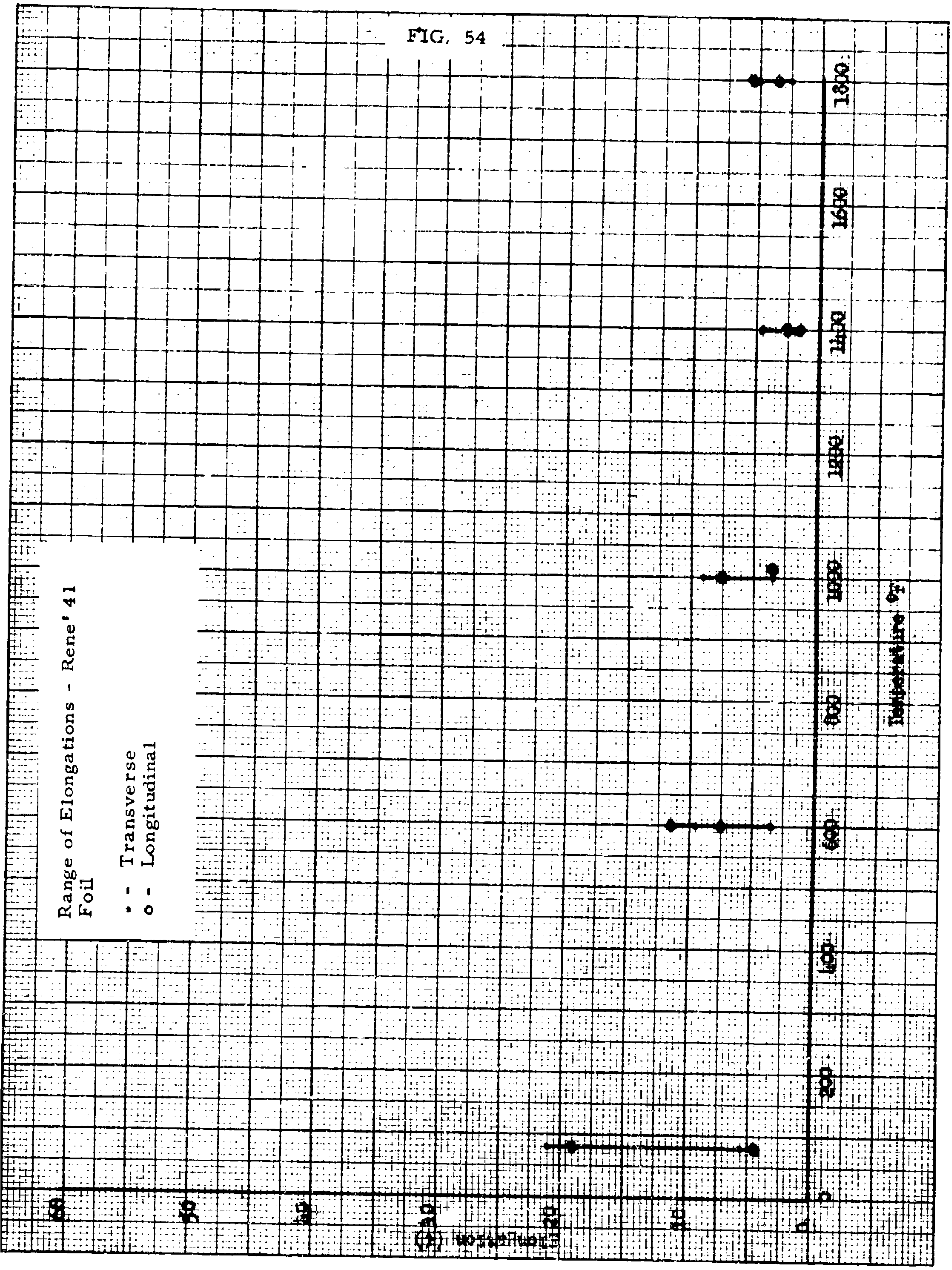


FIG. 53



K•E 10 X 10 TO THE ½ INCH 359-12G

FIG. 54



Range of Elongations - Rene' 41
Foil
• - Transverse
o - Longitudinal
Elongation (%)
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
Temperature °F

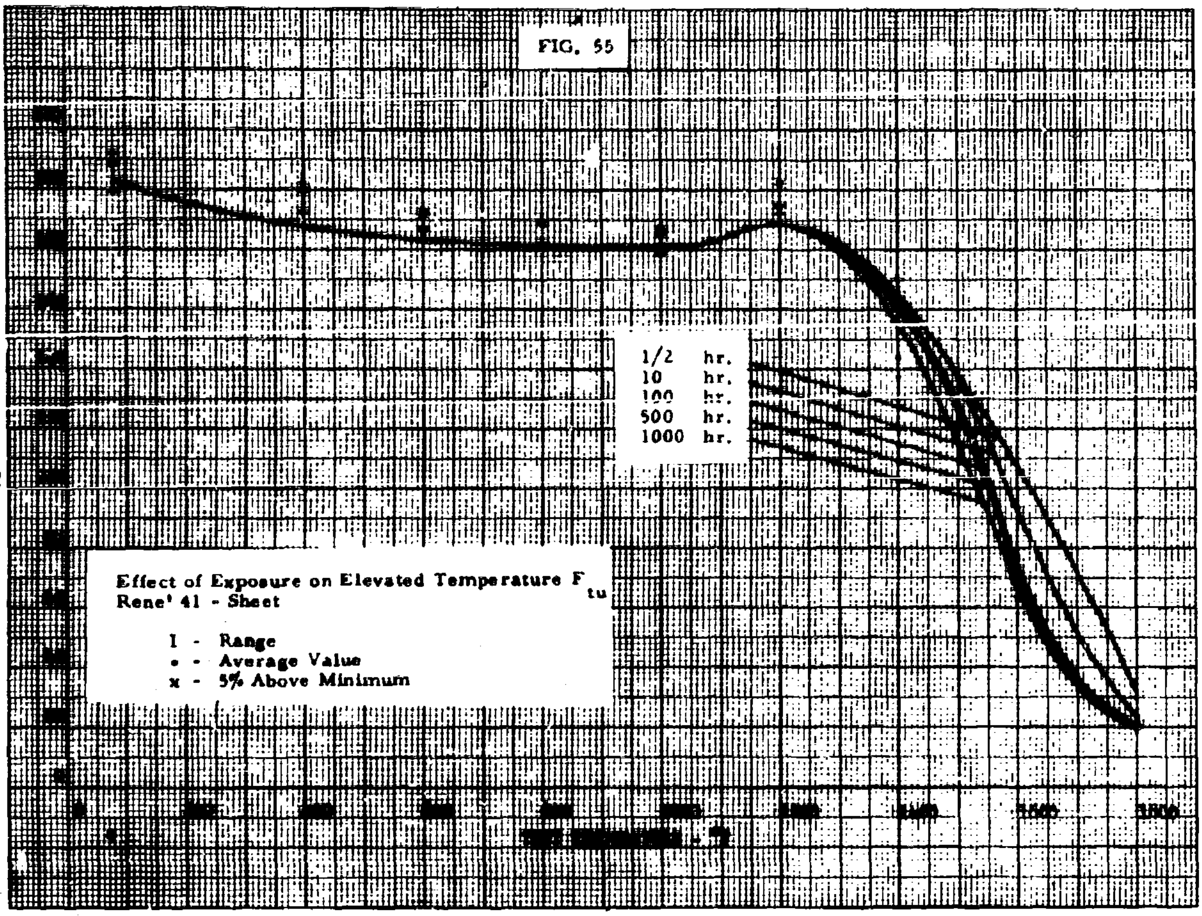


FIG. 55
1/2 hr.
10 hr.
100 hr.
500 hr.
1000 hr.
Effect of Exposure on Elevated Temperature F_{tu}
Rene' 41 - Sheet
I - Range
• - Average Value
x - 5% Above Minimum

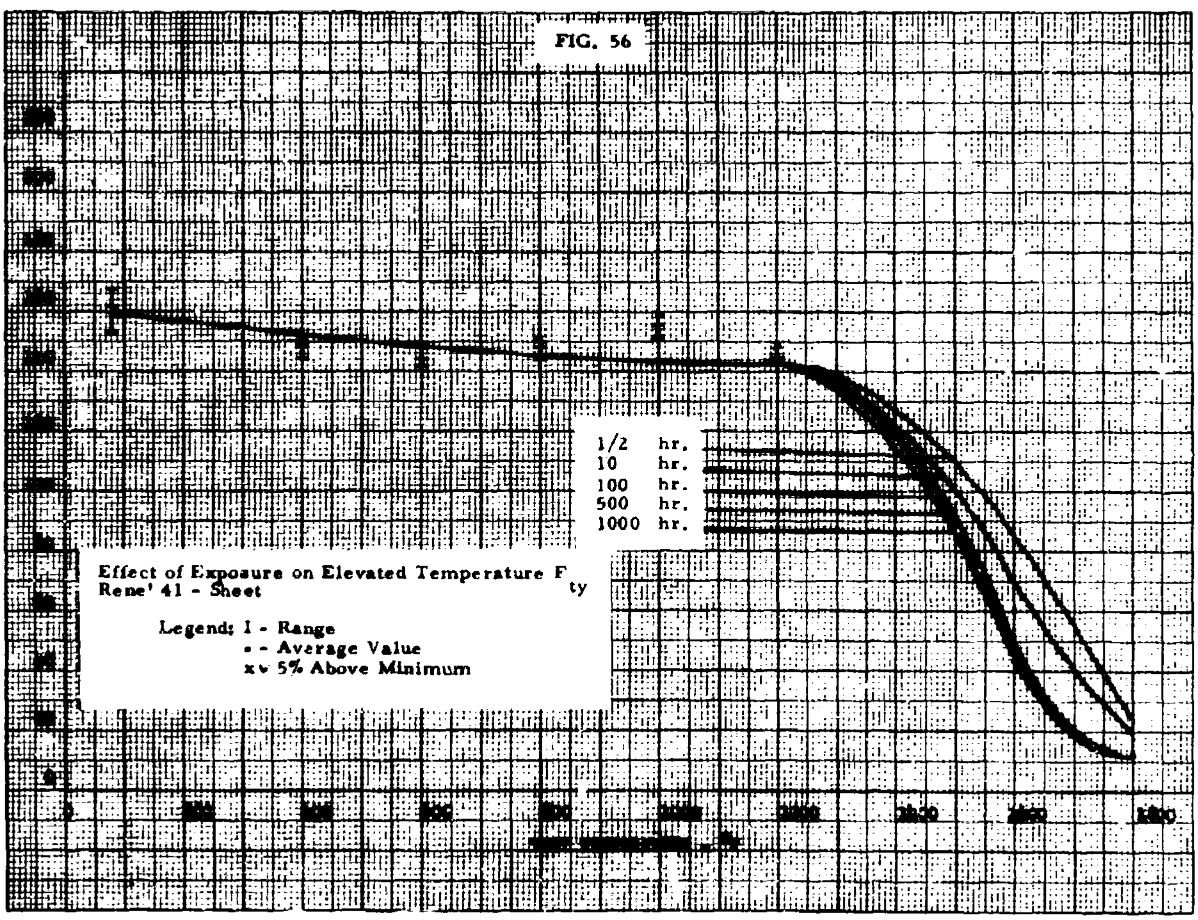


FIG. 56
1/2 hr.
10 hr.
100 hr.
500 hr.
1000 hr.
Effect of Expoaure on Elevated Temperature F_{ty}
Rene' 41 - Sheet
Legend: I - Range
• - Average Value
x - 5% Above Minimum

FIG. 57

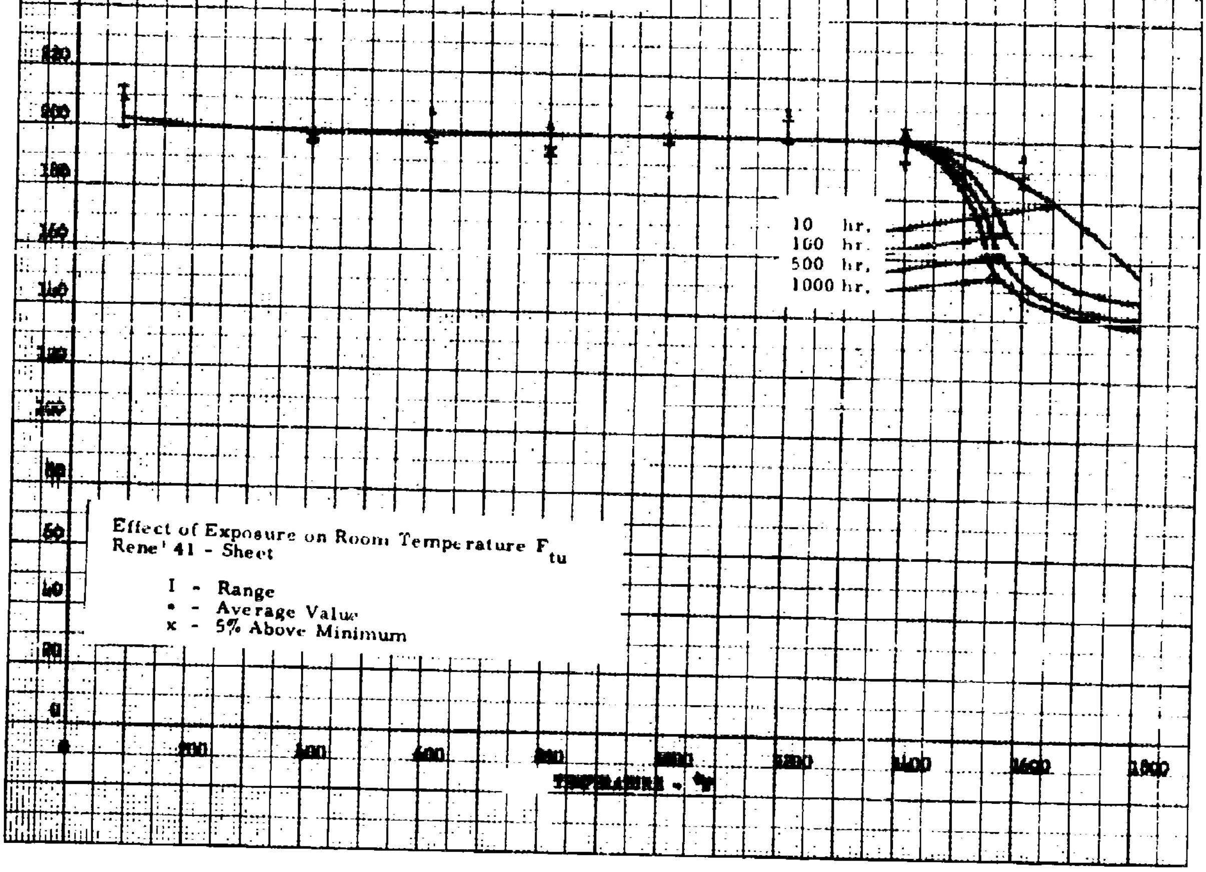
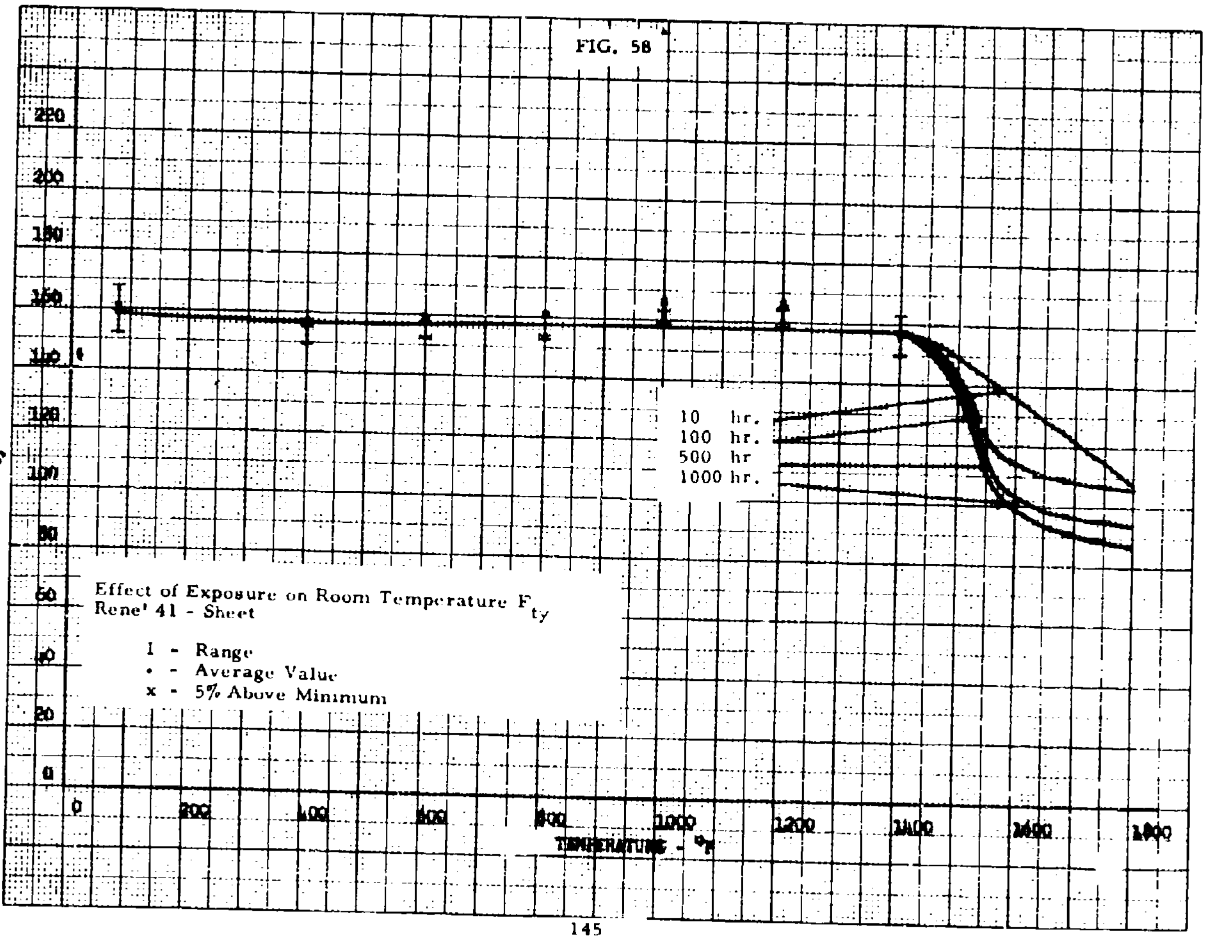

Effect of Exposure on Room Temperature F_{tu}
Rene' 41 - Sheet
I - Range
• - Average Value
x - 5% Above Minimum
10 hr.
100 hr.
500 hr.
1000 hr.
F_{tu} - KSI
TEMPERATURE - °F
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 58


Effect of Exposure on Room Temperature F_{ty}
Rene' 41 - Sheet
I - Range
• - Average Value
x - 5% Above Minimum
10 hr.
100 hr.
500 hr
1000 hr.
F_{ty} - KSI
TEMPERATURE - °F
220
200
180
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
1400
1600
1800

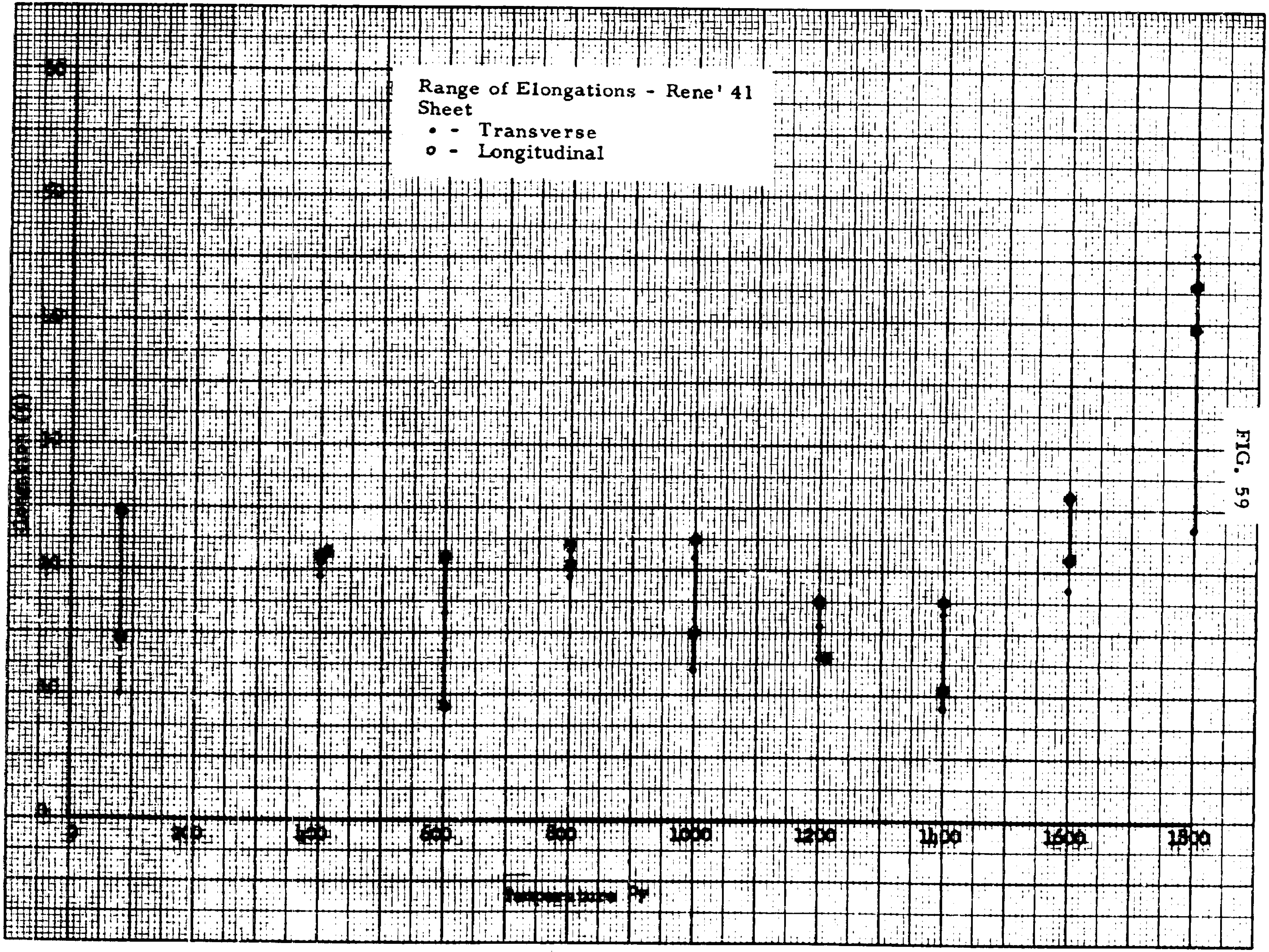

Range of Elongations - Rene' 41
Sheet
• - Transverse
o - Longitudinal

FIG. 59

FIG. 60

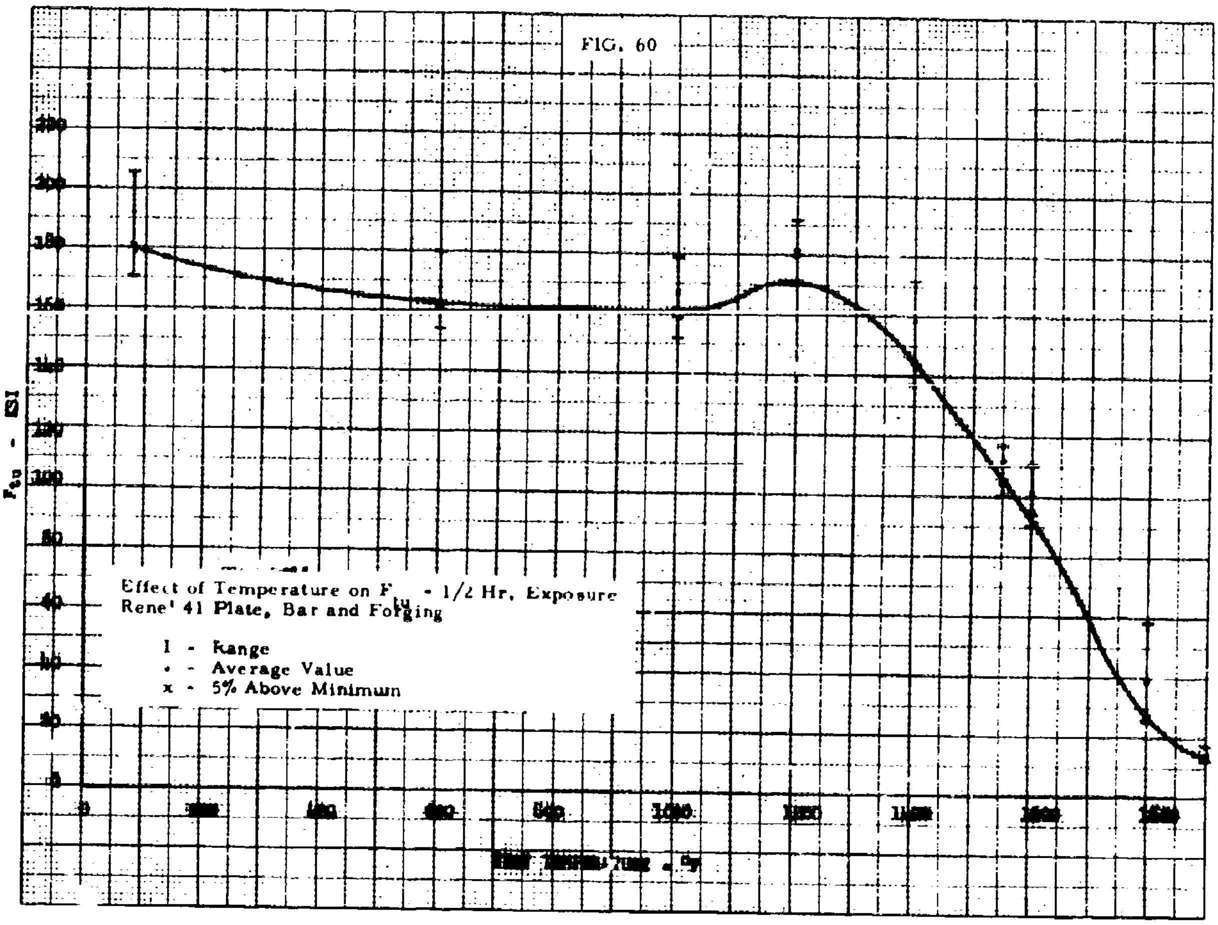
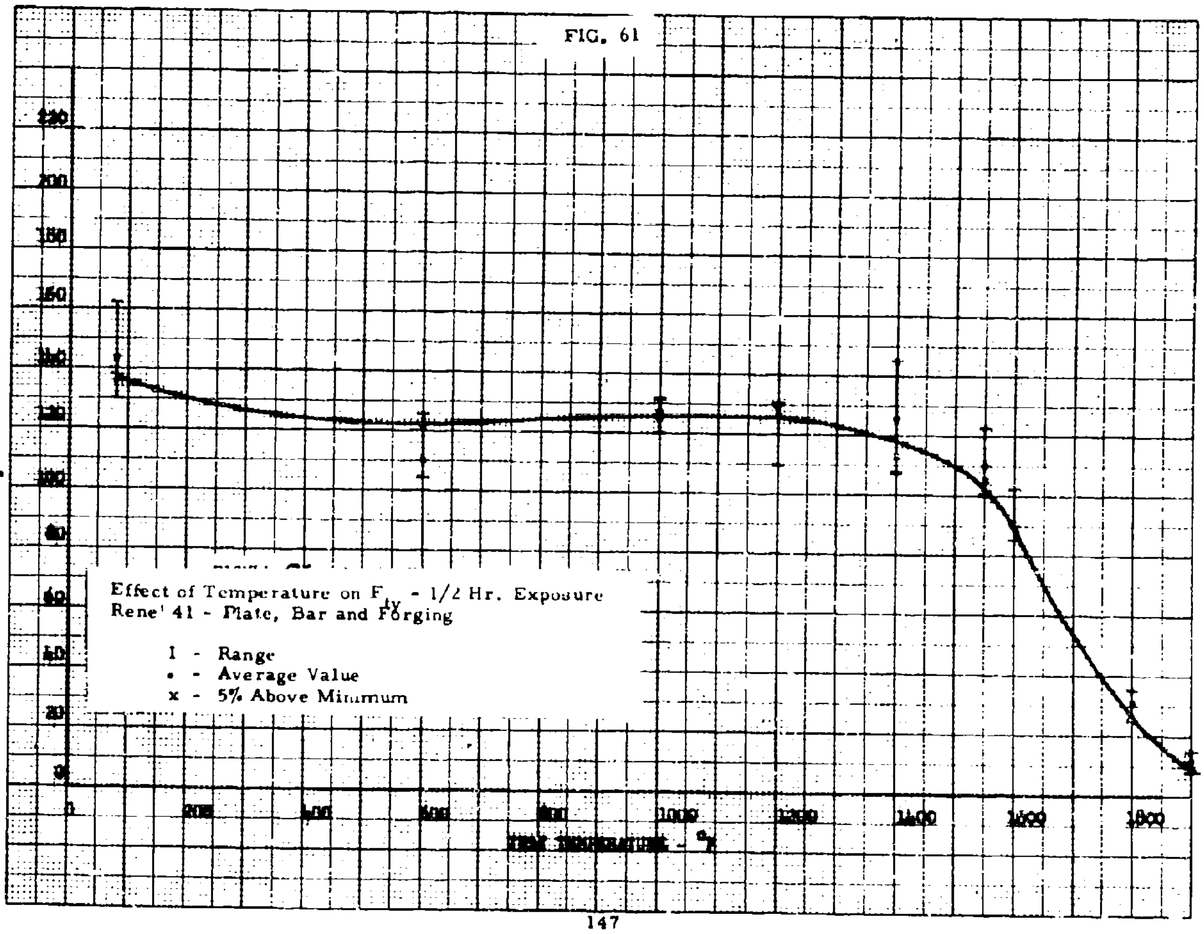
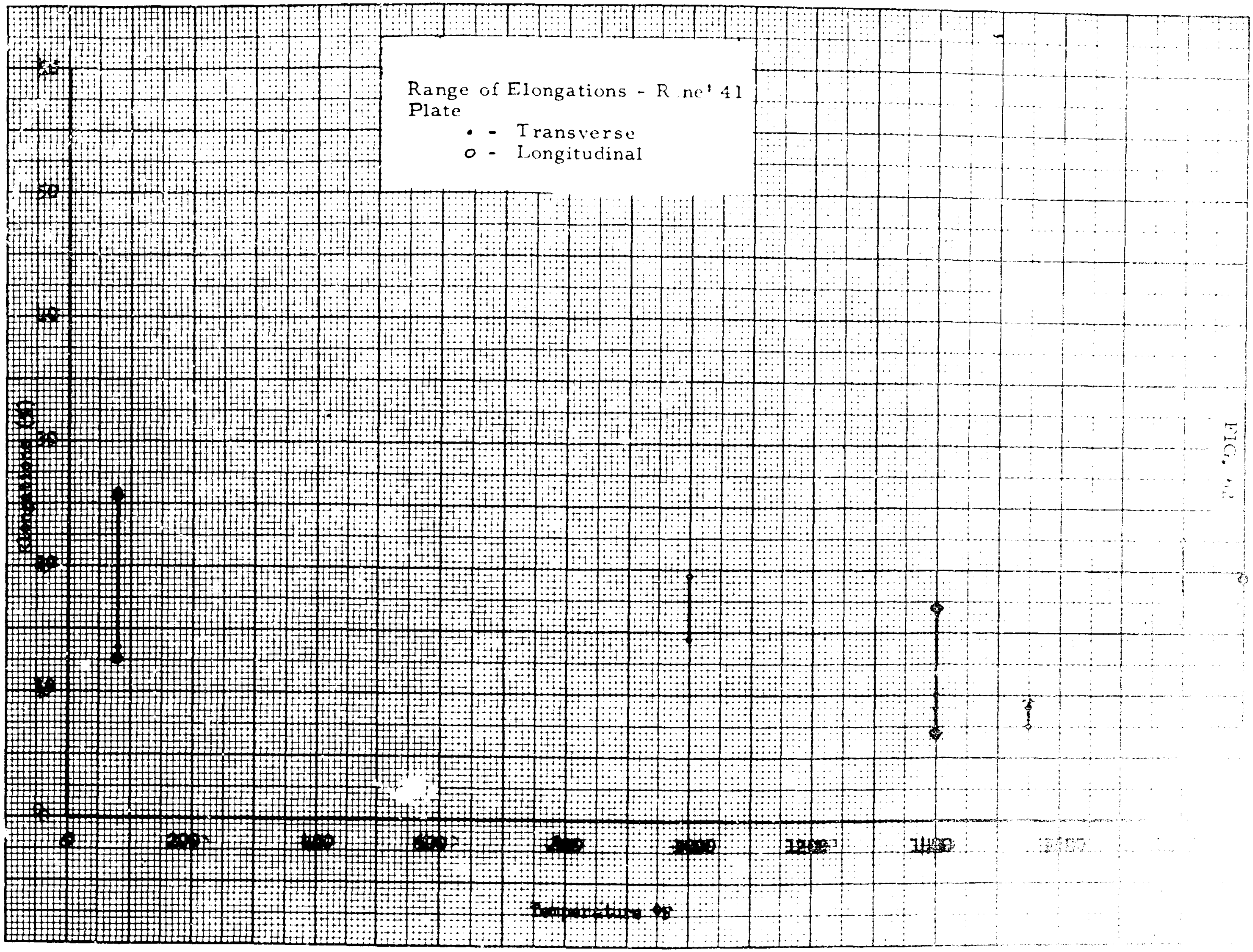

Effect of Temperature on F_{tu} - 1/2 Hr. Exposure
Rene' 41 Plate, Bar and Forging
I - Range
• - Average Value
x - 5% Above Minimum
F_{tu} - KSI

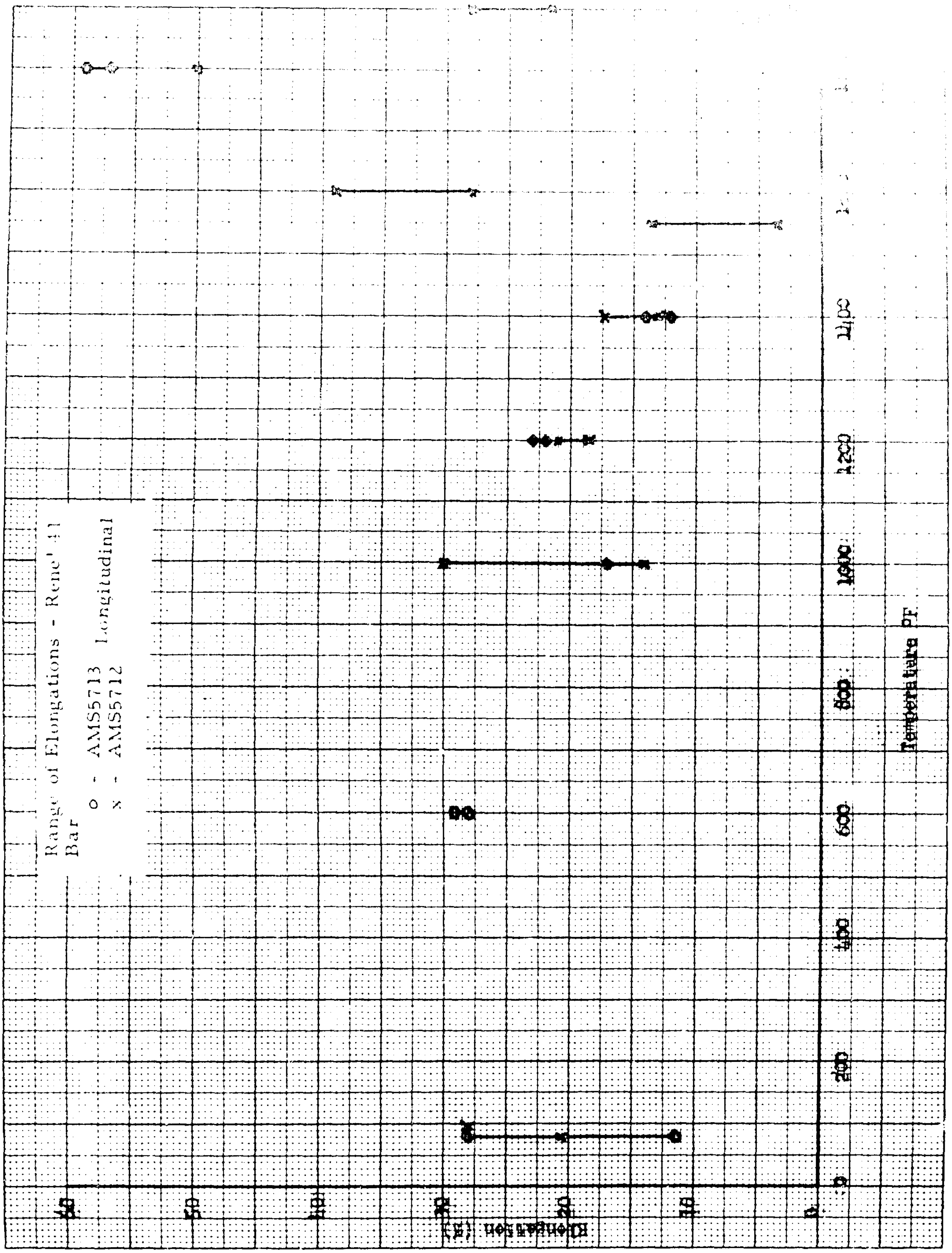
FIG. 61


Effect of Temperature on F_{ty} - 1/2 Hr. Exposure
Rene' 41 - Plate, Bar and Forging
I - Range
• - Average Value
x - 5% Above Minimum
F_{ty} - KSI



Range of Elongations - R ne' 41
Plate
• - Transverse
o - Longitudinal
0
200
400
600
800
1000
1200
1400
Temperature °F
10
20
30
40
50

FIG. 62



Range of Elongations - Rene' 41
Bar
o - AMS5713 Longitudinal
x - AMS5712
Elongation (%)
0
10
20
30
40
50
60
Temperature °F
0
200
400
600
800
1000
1200
1400

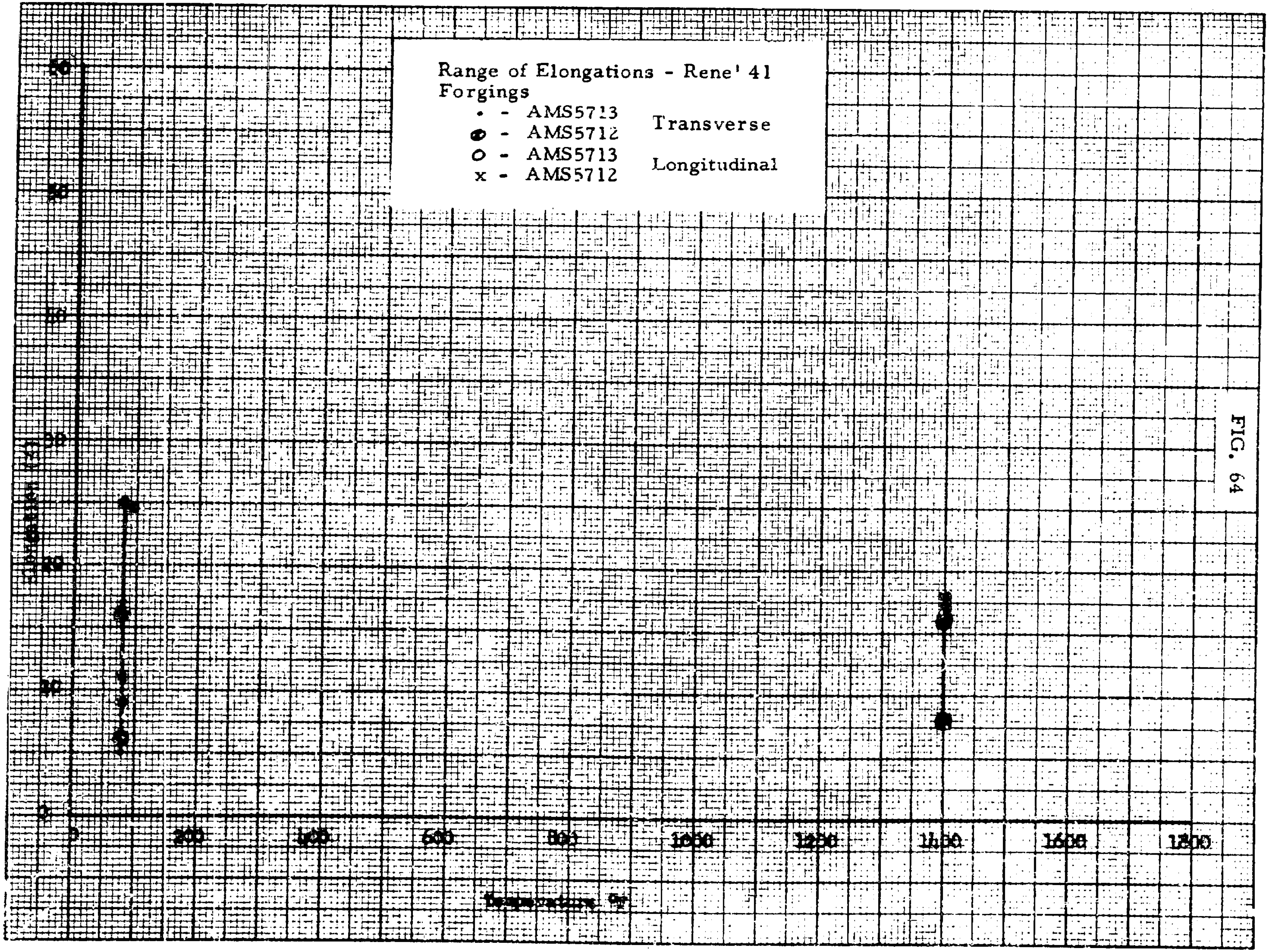
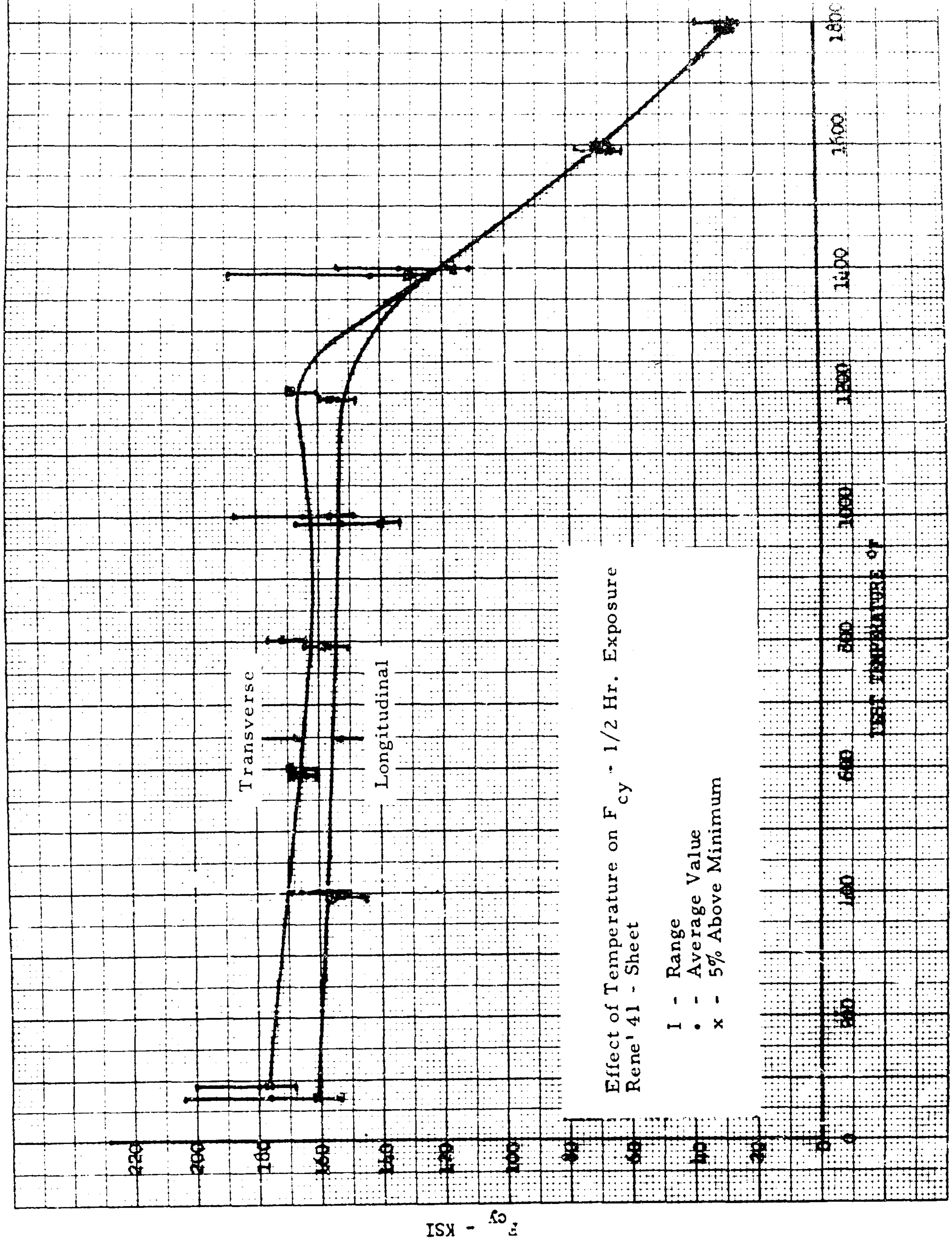

Range of Elongations - Rene' 41
Forgings
• - AMS5713
⊕ - AMS5712
Transverse
O - AMS5713
x - AMS5712
Longitudinal
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 64

SECTION VII

SECTION 7.1.2 COMPRESSION

FIG. 65



Effect of Temperature on F_{cy} - 1/2 Hr. Exposure
Rene' 41 - Sheet
I - Range
• - Average Value
x - 5% Above Minimum
Transverse
Longitudinal
TEST TEMPERATURE °F
0
200
400
600
800
1000
1200
1400
1600
1800
20
40
60
80
100
120
140
160
180
200
220
F_{cy} - KSI

FIG. 66

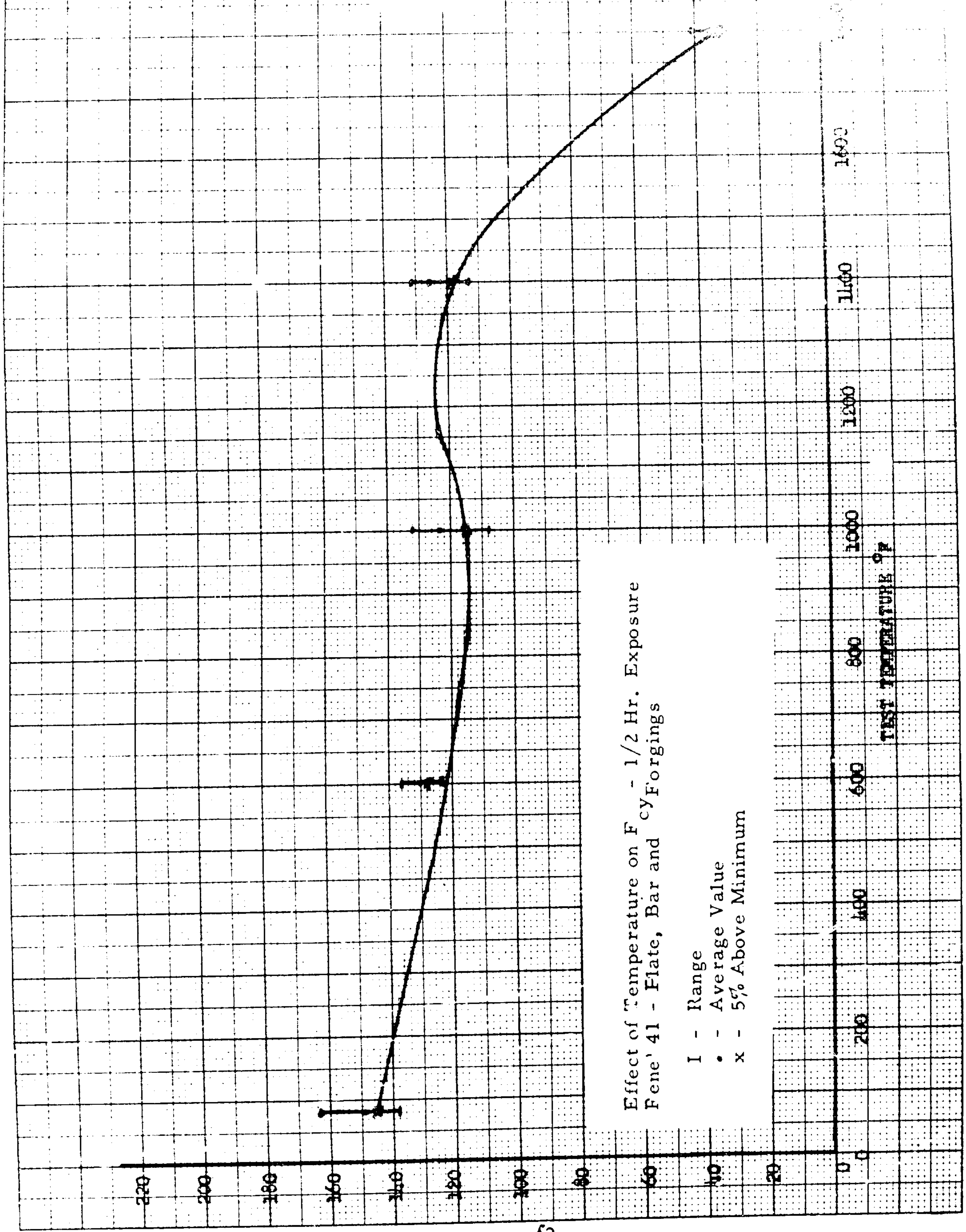
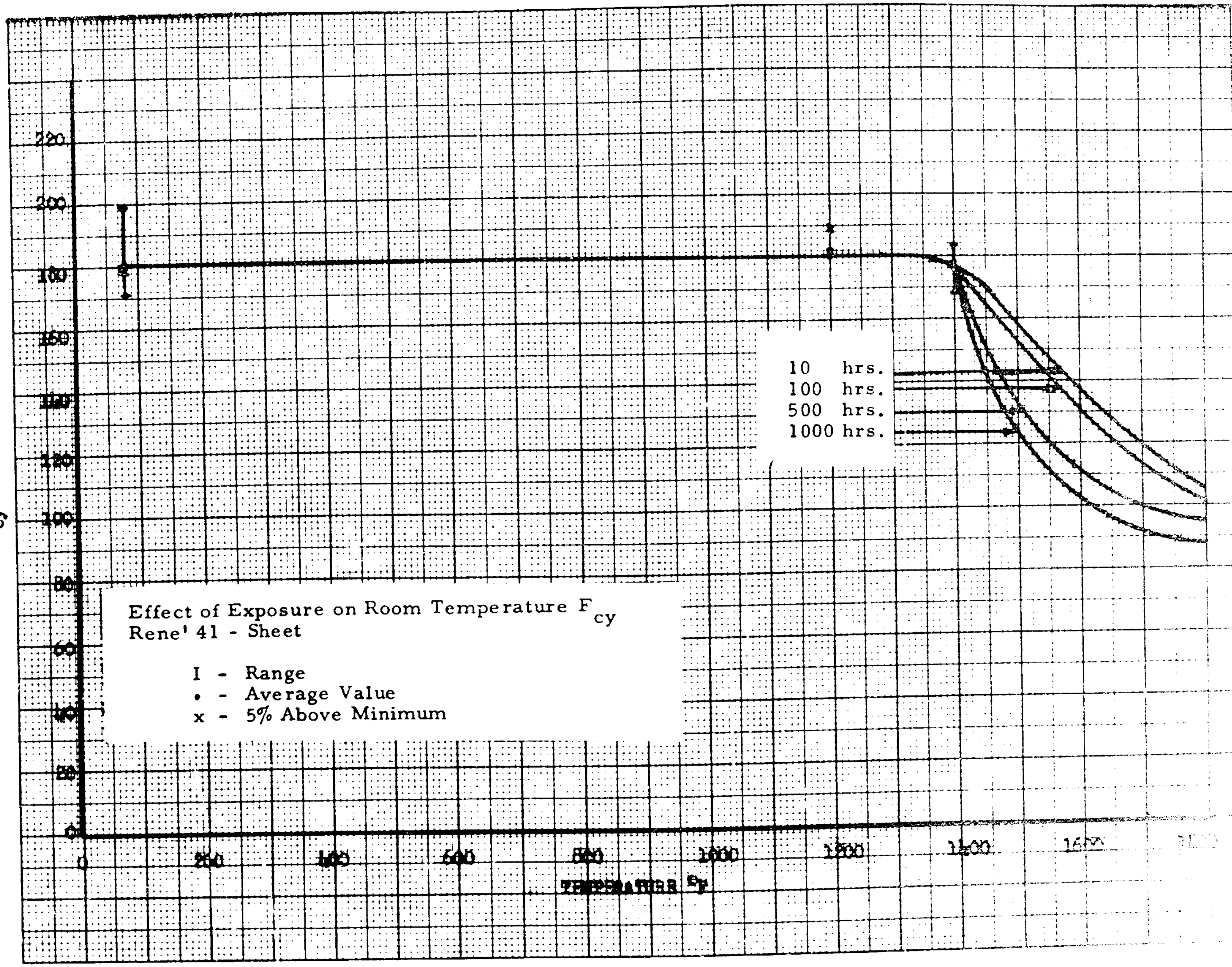
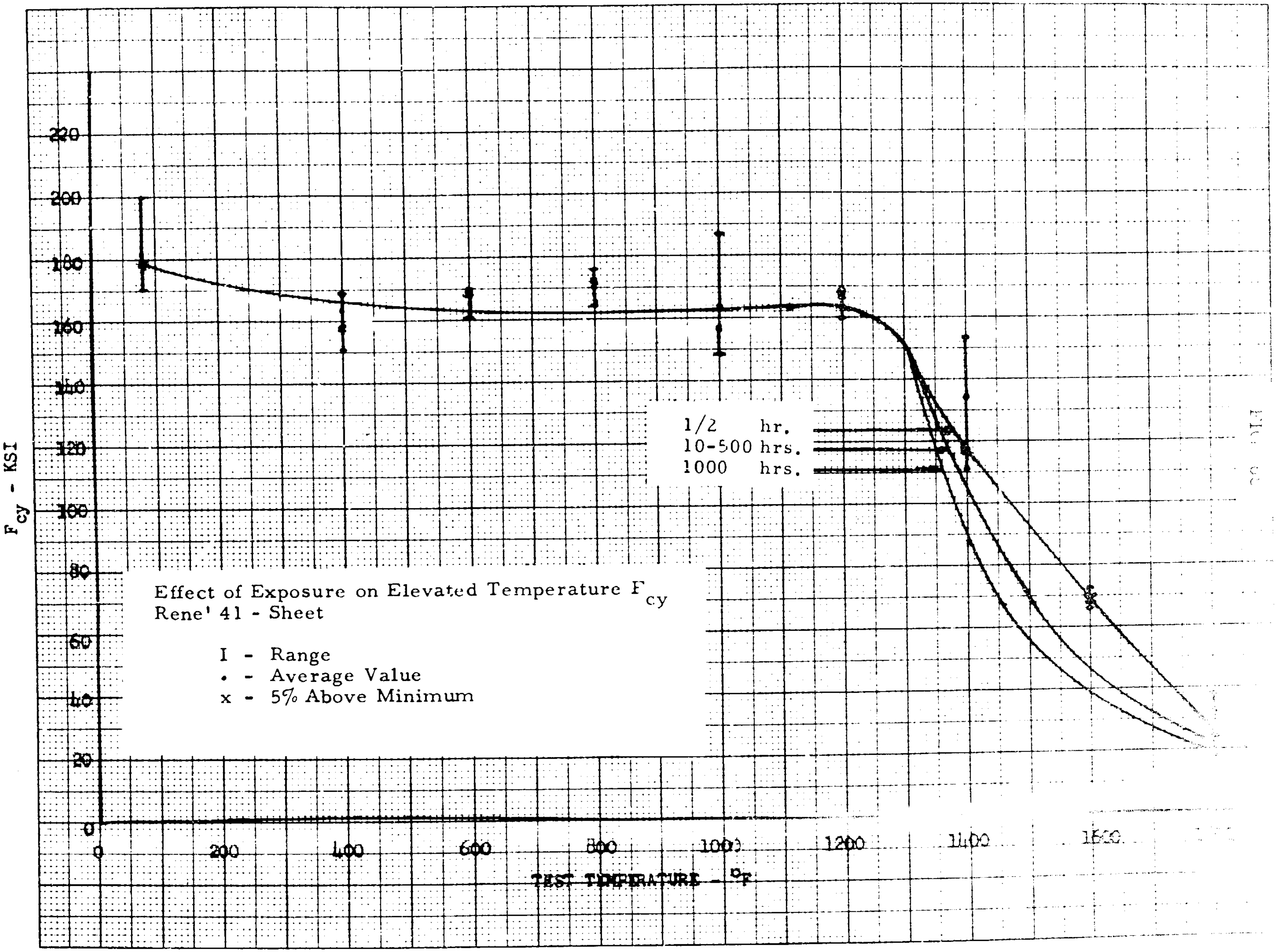

Effect of Temperature on Fcy - 1/2 Hr. Exposure
Fene' 41 - Flate, Bar and Forgings
I - Range
• - Average Value
x - 5% Above Minimum
TEST TEMPERATURE °F
0
200
400
600
800
1000
1200
1400
1600
0
20
40
60
80
100
120
140
160
180
200
220
Fcy - KSI

FIG. 67


Effect of Exposure on Room Temperature F_{cy}
Rene' 41 - Sheet
I - Range
• - Average Value
x - 5% Above Minimum
10 hrs.
100 hrs.
500 hrs.
1000 hrs.
F_{cy} - KSI
TEMPERATURE °F
0
20
40
60
80
100
120
140
160
180
200
220
200
400
600
800
1000
1200
1400
1600


Effect of Exposure on Elevated Temperature F_{cy}
Rene' 41 - Sheet
I - Range
. - Average Value
x - 5% Above Minimum
1/2 hr.
10-500 hrs.
1000 hrs.
F_{cy} - KSI
TEST TEMPERATURE - °F
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600

SECTION VII

SECTION 7.1.3 BEARING

FIG. 69

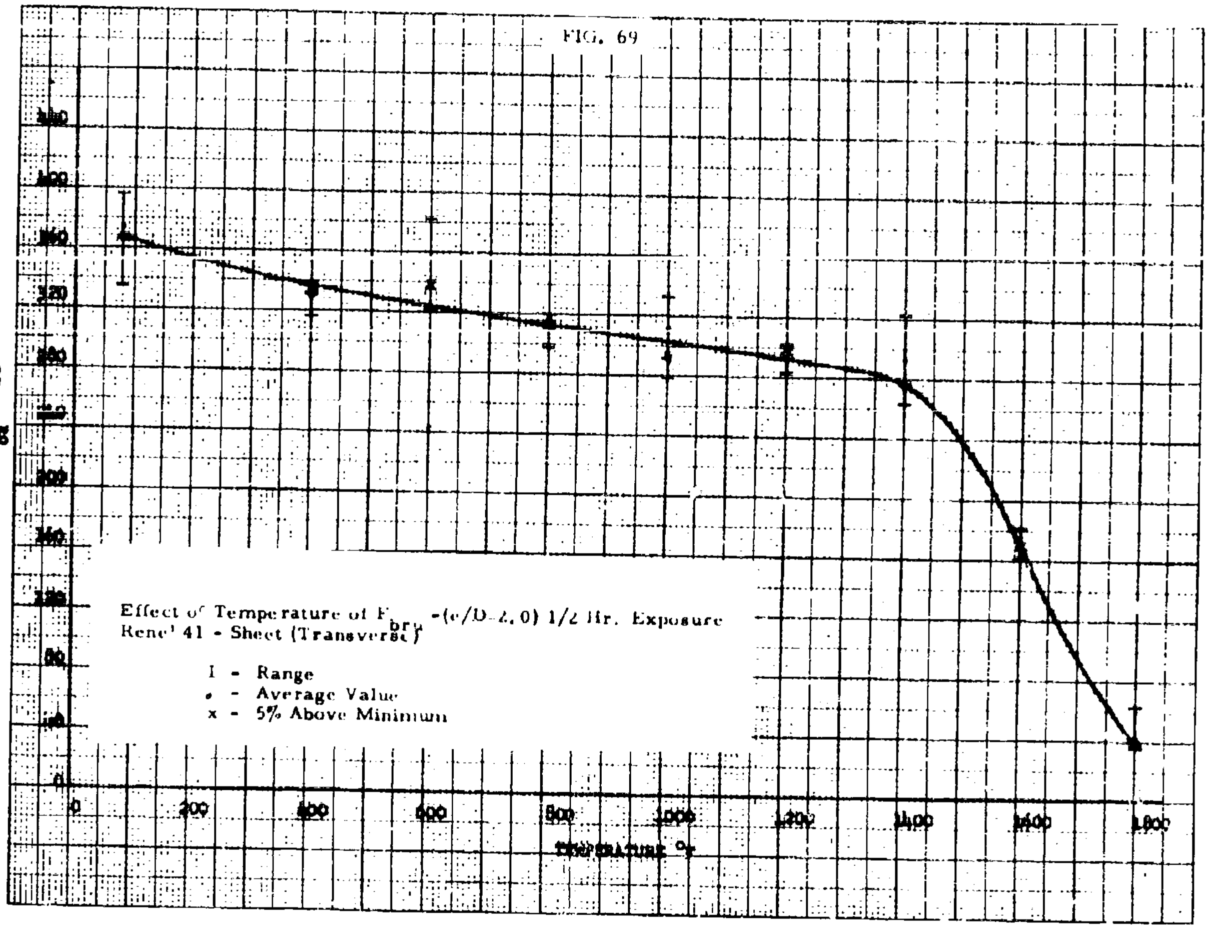

Effect of Temperature of F_{bry} -(e/D=2.0) 1/2 Hr. Exposure
Rene' 41 - Sheet (Transverse)
I - Range
• - Average Value
x - 5% Above Minimum
F_{bx} - KSI
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE °F

FIG. 70

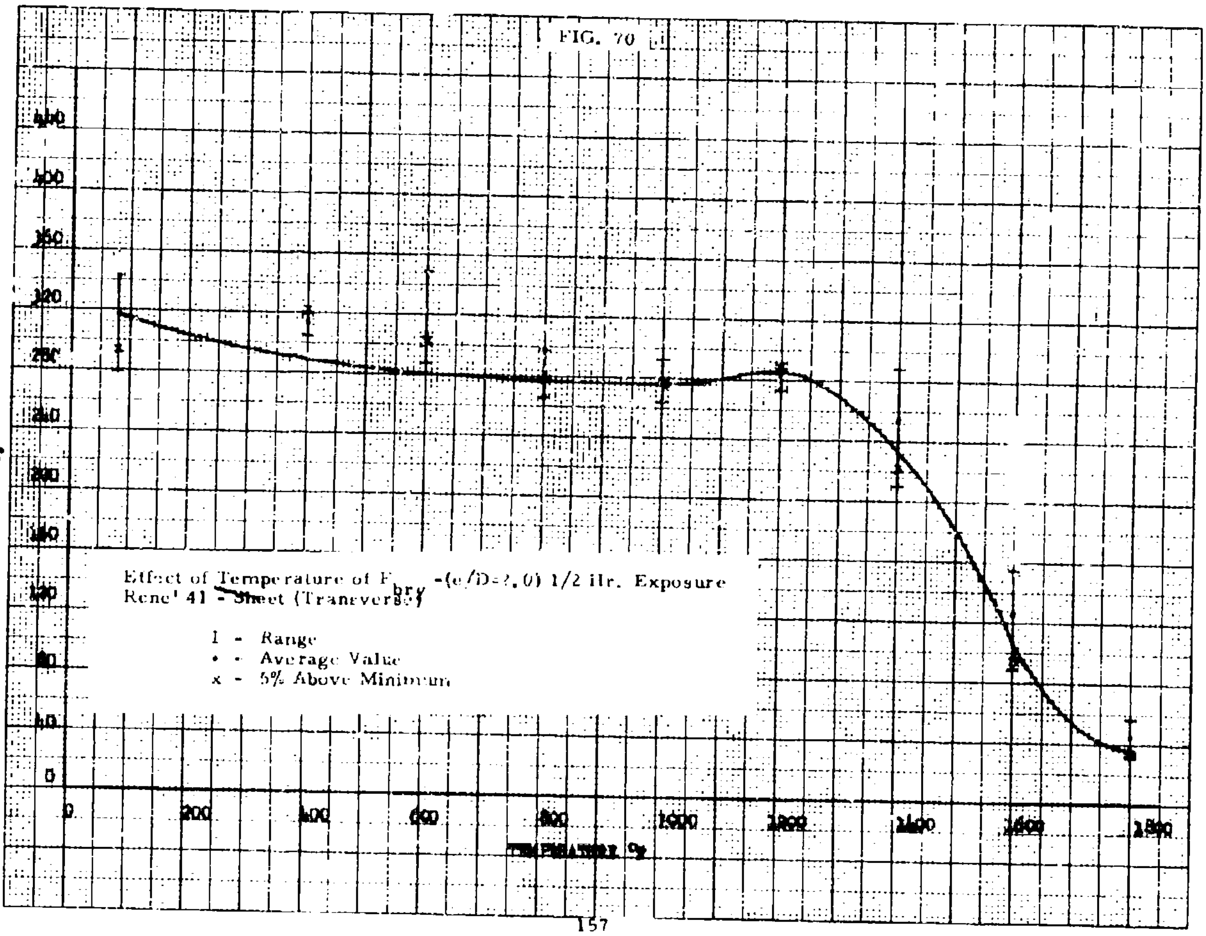

Effect of Temperature of F_{bry} -(e/D=2.0) 1/2 Hr. Exposure
Rene' 41 - Sheet (Transverse)
I - Range
• - Average Value
x - 5% Above Minimum
F_{by} - KSI
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE °F

FIG. 71

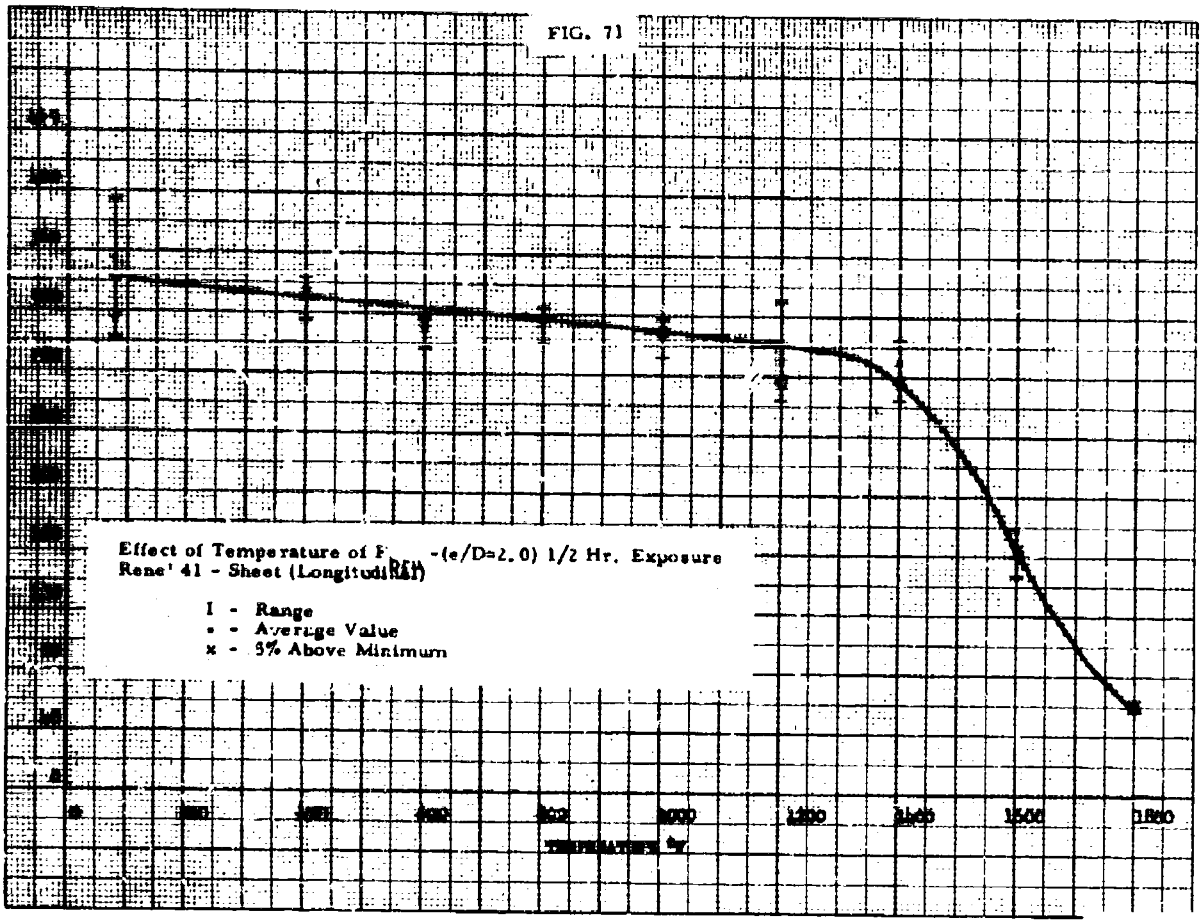
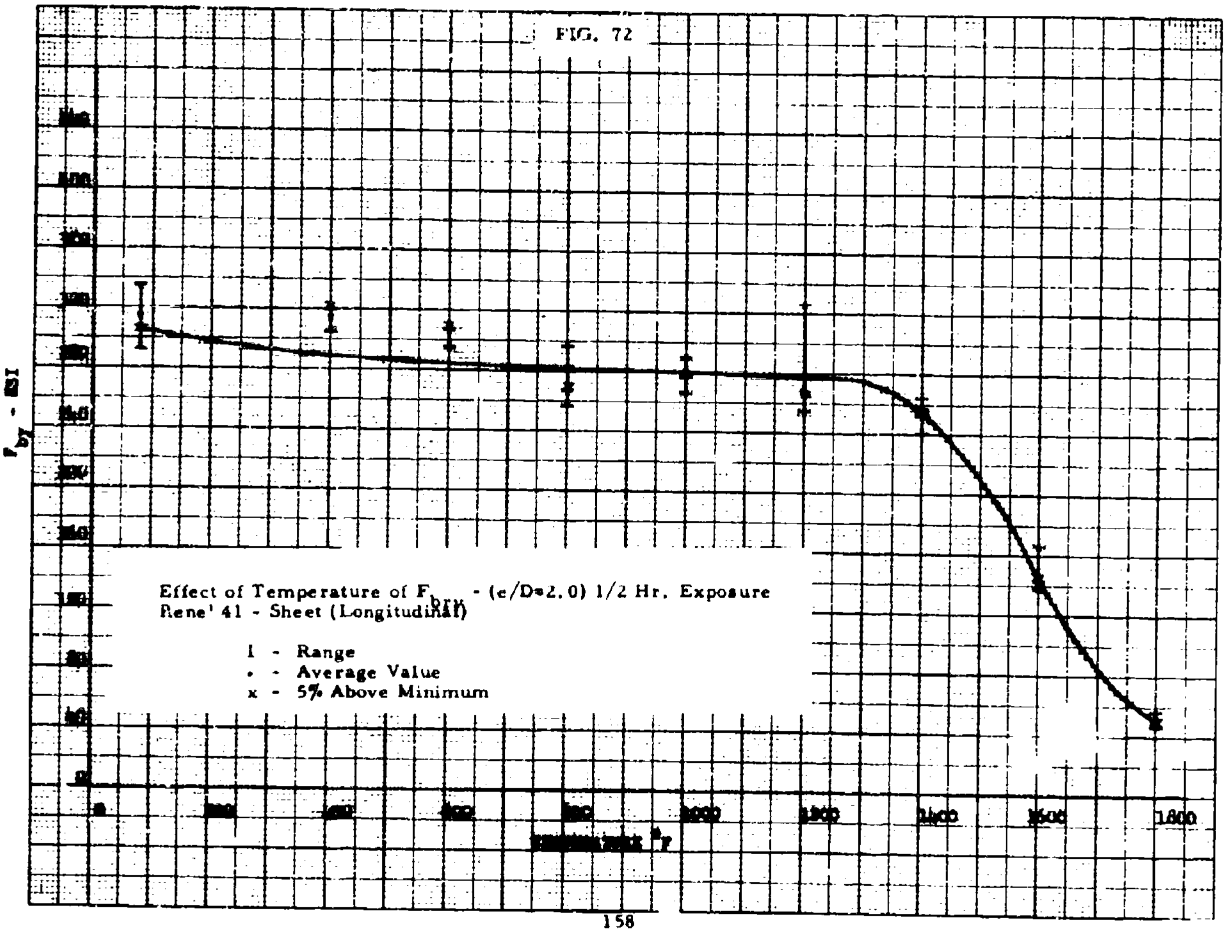

Effect of Temperature of F_{bru} -(e/D=2.0) 1/2 Hr. Exposure
Rene' 41 - Sheet (Longitudinal)
I - Range
• - Average Value
x - 5% Above Minimum

FIG. 72


F_{by} - KSI
Effect of Temperature of F_{bru} - (e/D=2.0) 1/2 Hr. Exposure
Rene' 41 - Sheet (Longitudinal)
I - Range
• - Average Value
x - 5% Above Minimum

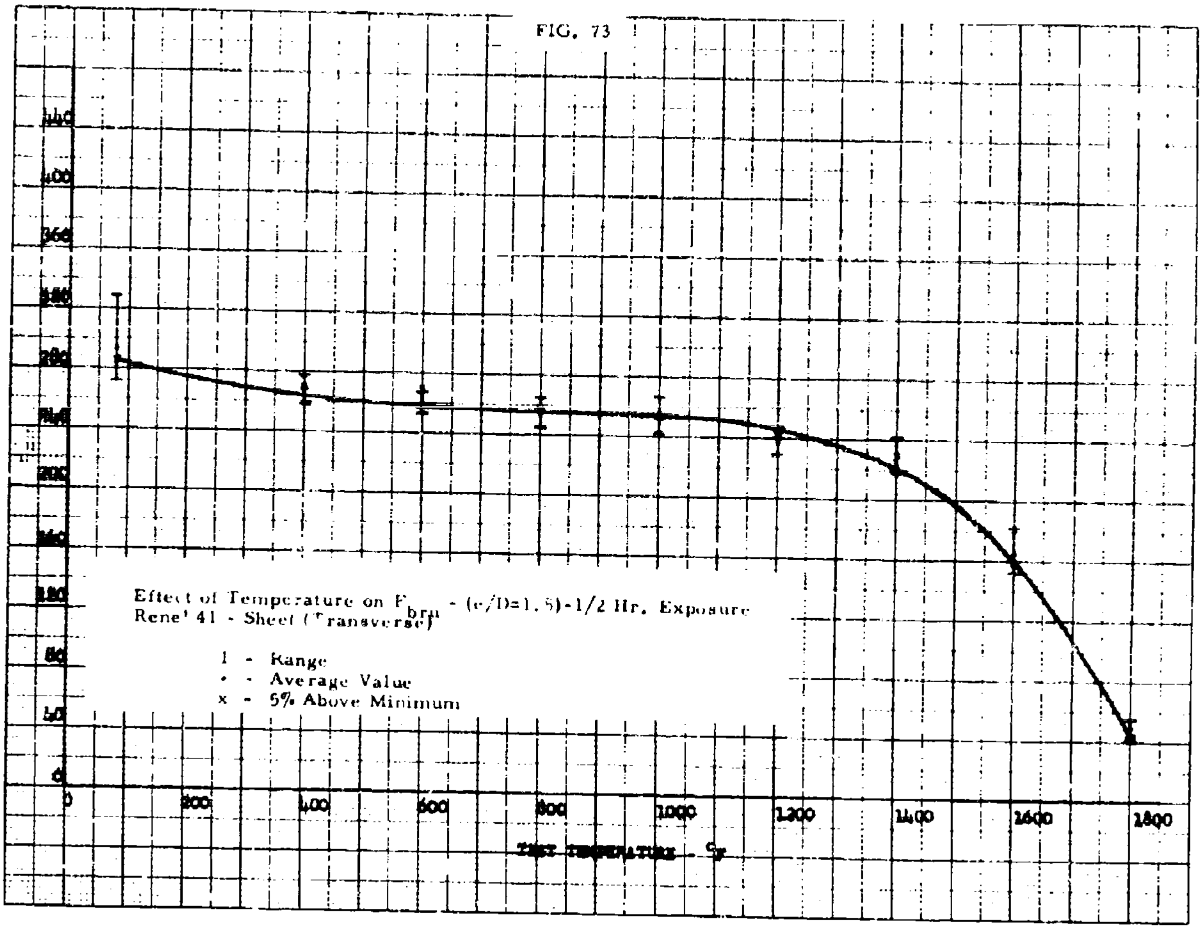


FIG. 73
Effect of Temperature on F_{bru} - (e/D=1.5)-1/2 Hr. Exposure
Rene' 41 - Sheet (Transverse)
I - Range
• - Average Value
x - 5% Above Minimum
0
200
400
600
800
1000
1200
1400
1600
1800
40
80
120
160
200
240
280
320
360
400
440

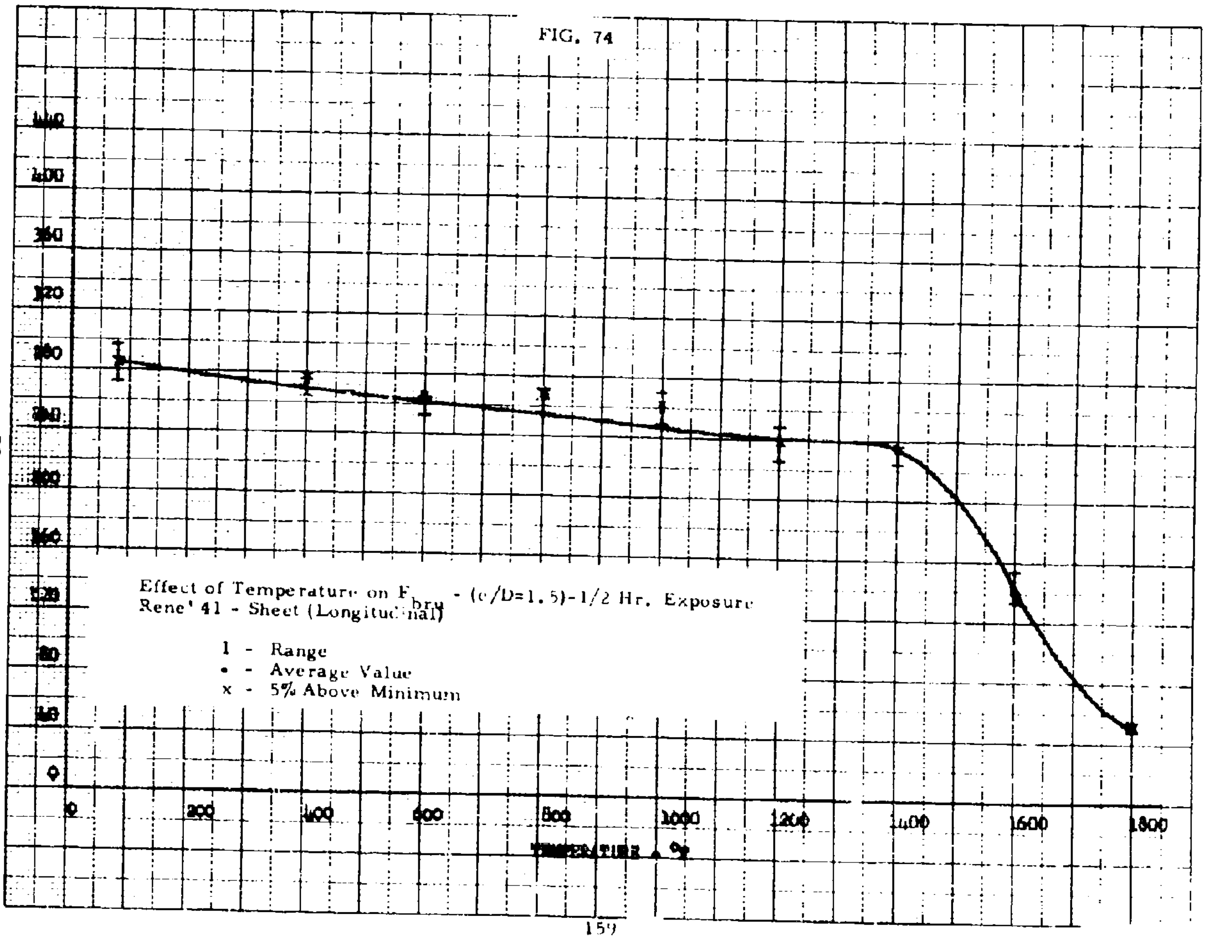


FIG. 74
Effect of Temperature on F_{bru} - (e/D=1.5)-1/2 Hr. Exposure
Rene' 41 - Sheet (Longitudinal)
I - Range
• - Average Value
x - 5% Above Minimum
0
200
400
600
800
1000
1200
1400
1600
1800
0
40
80
120
160
200
240
280
320
360
400
440

FIG. 75

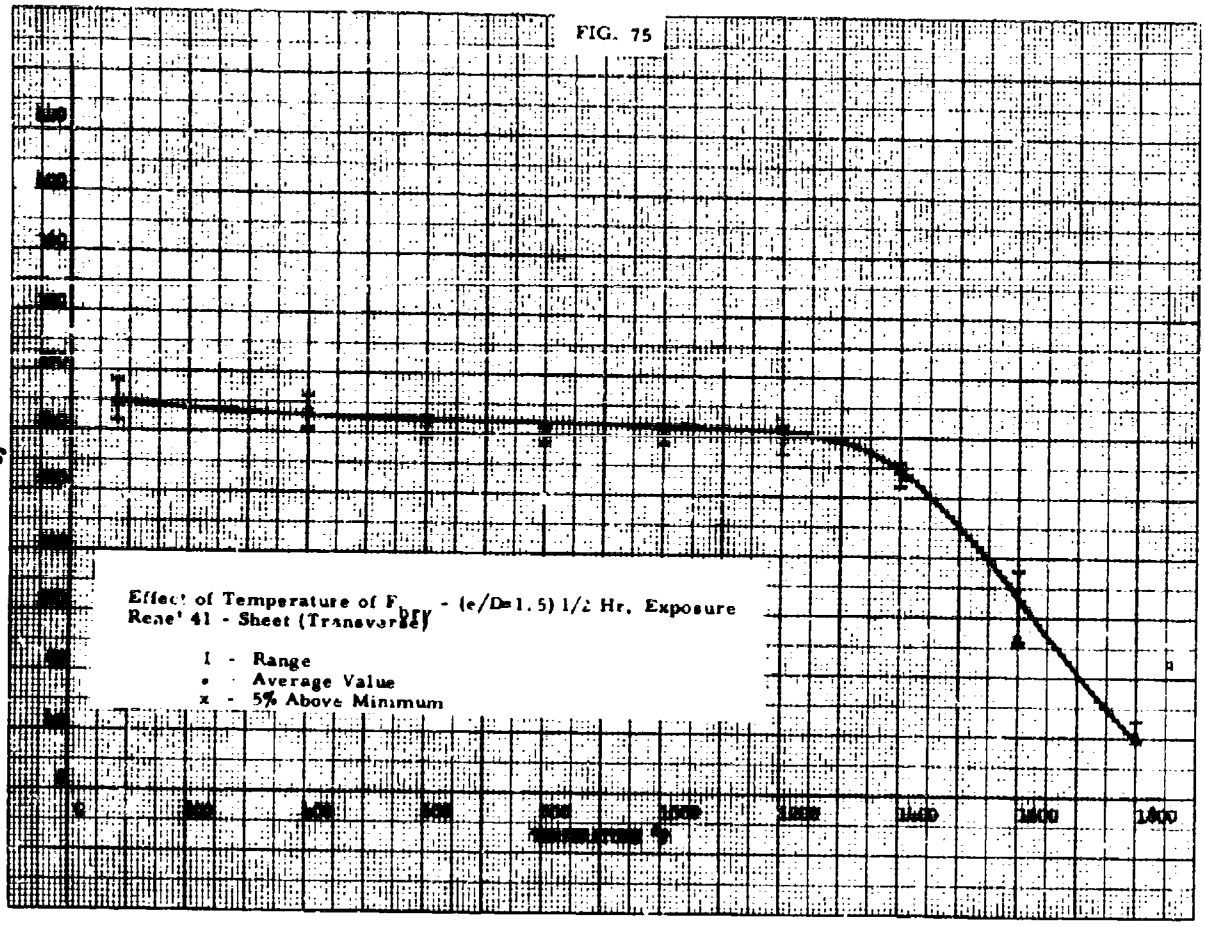
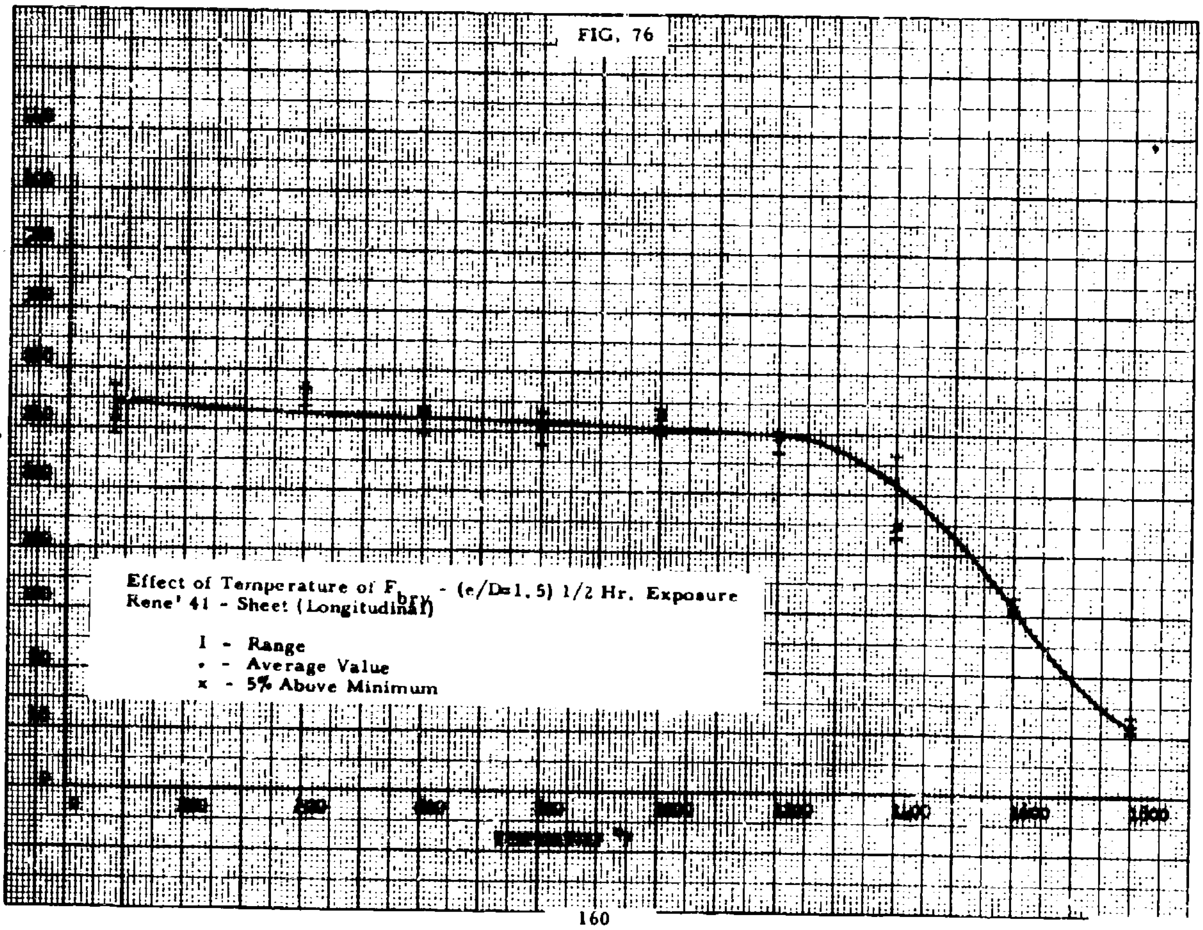

Effect of Temperature of F_{bry} - (e/D=1.5) 1/2 Hr. Exposure
Rene' 41 - Sheet (Transverse)
I - Range
• - Average Value
x - 5% Above Minimum
F_{bry} - KSI

FIG. 76


Effect of Temperature of F_{bry} - (e/D=1.5) 1/2 Hr. Exposure
Rene' 41 - Sheet (Longitudinal)
I - Range
• - Average Value
x - 5% Above Minimum
F_{bry} - KSI

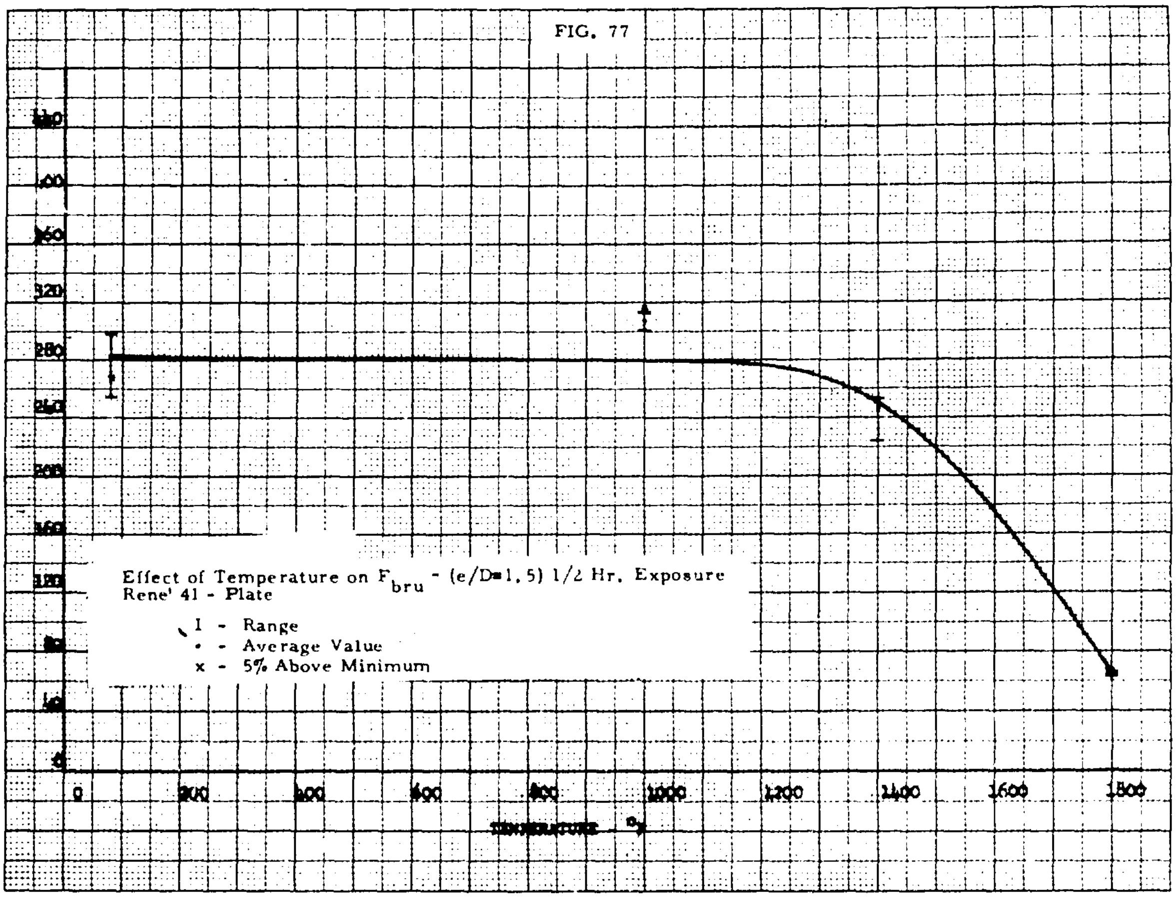


FIG. 77
Effect of Temperature on F_{bru} - (e/D=1.5) 1/2 Hr. Exposure
Rene' 41 - Plate
I - Range
• - Average Value
x - 5% Above Minimum
F_{bu} - KSI
TEMPERATURE - °F

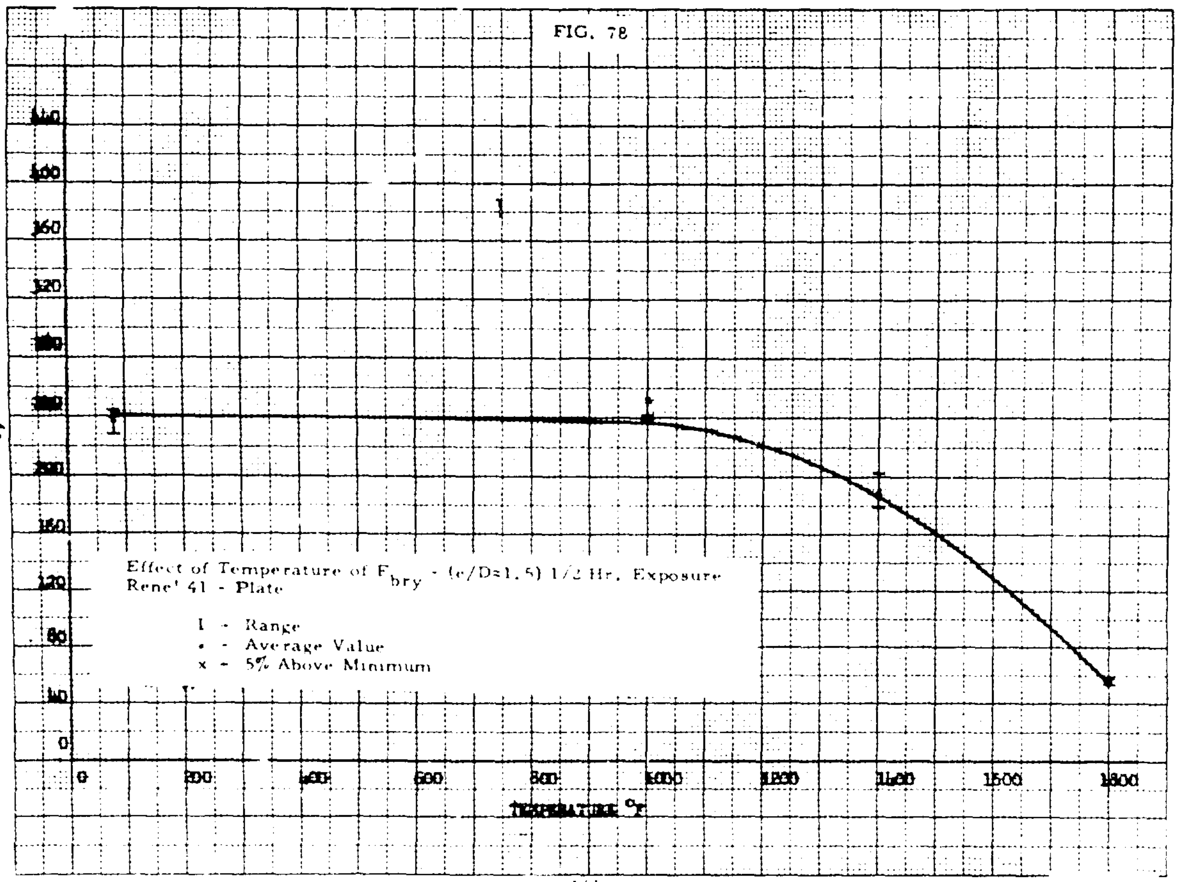


FIG. 78
Effect of Temperature of F_{bry} - (e/D=1.5) 1/2 Hr. Exposure
Rene' 41 - Plate
I - Range
• - Average Value
x - 5% Above Minimum
F_{by} - KSI
TEMPERATURE °F

FIG. 79

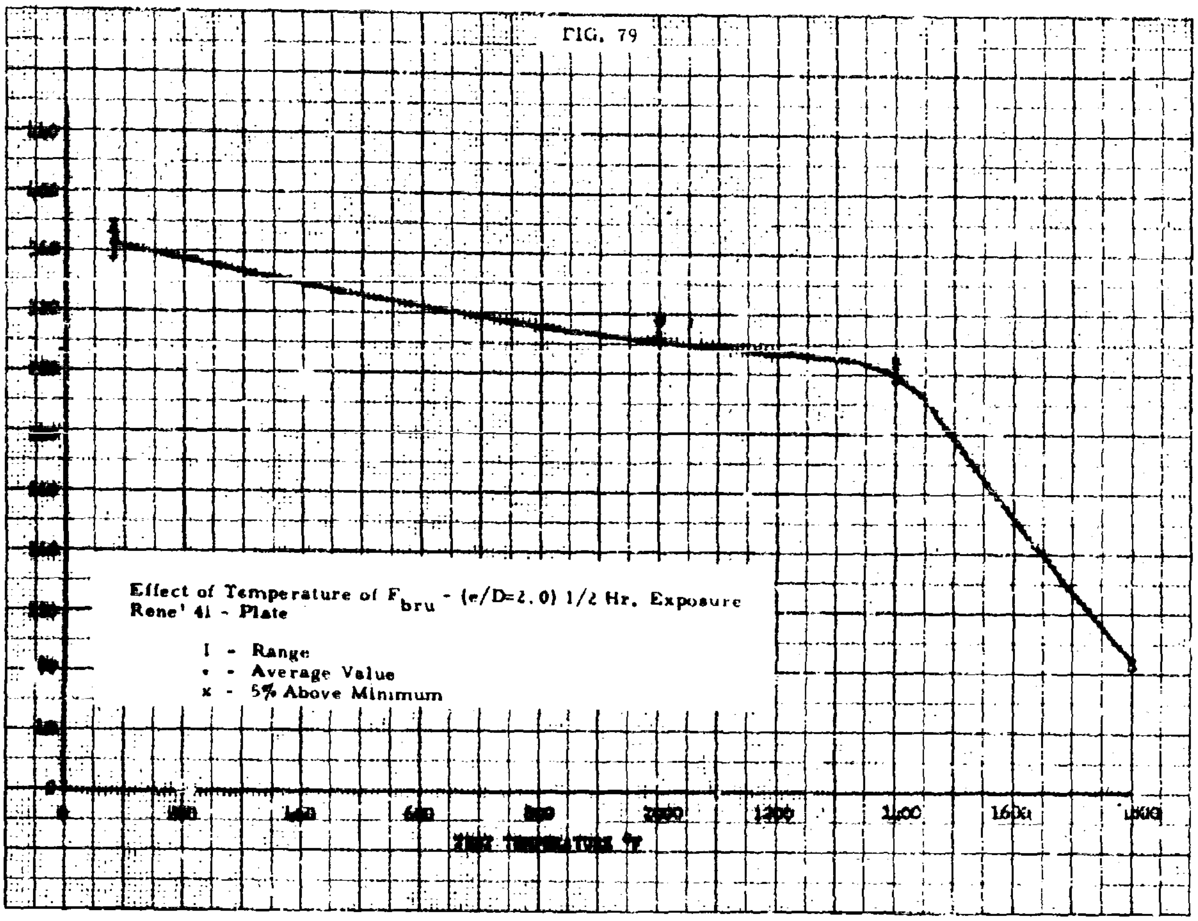

Effect of Temperature of F_{bru} - (e/D=2.0) 1/2 Hr. Exposure
Rene' 41 - Plate
I - Range
• - Average Value
x - 5% Above Minimum
F_{bu} - KSI
1200
1400
1600
1800

FIG. 80

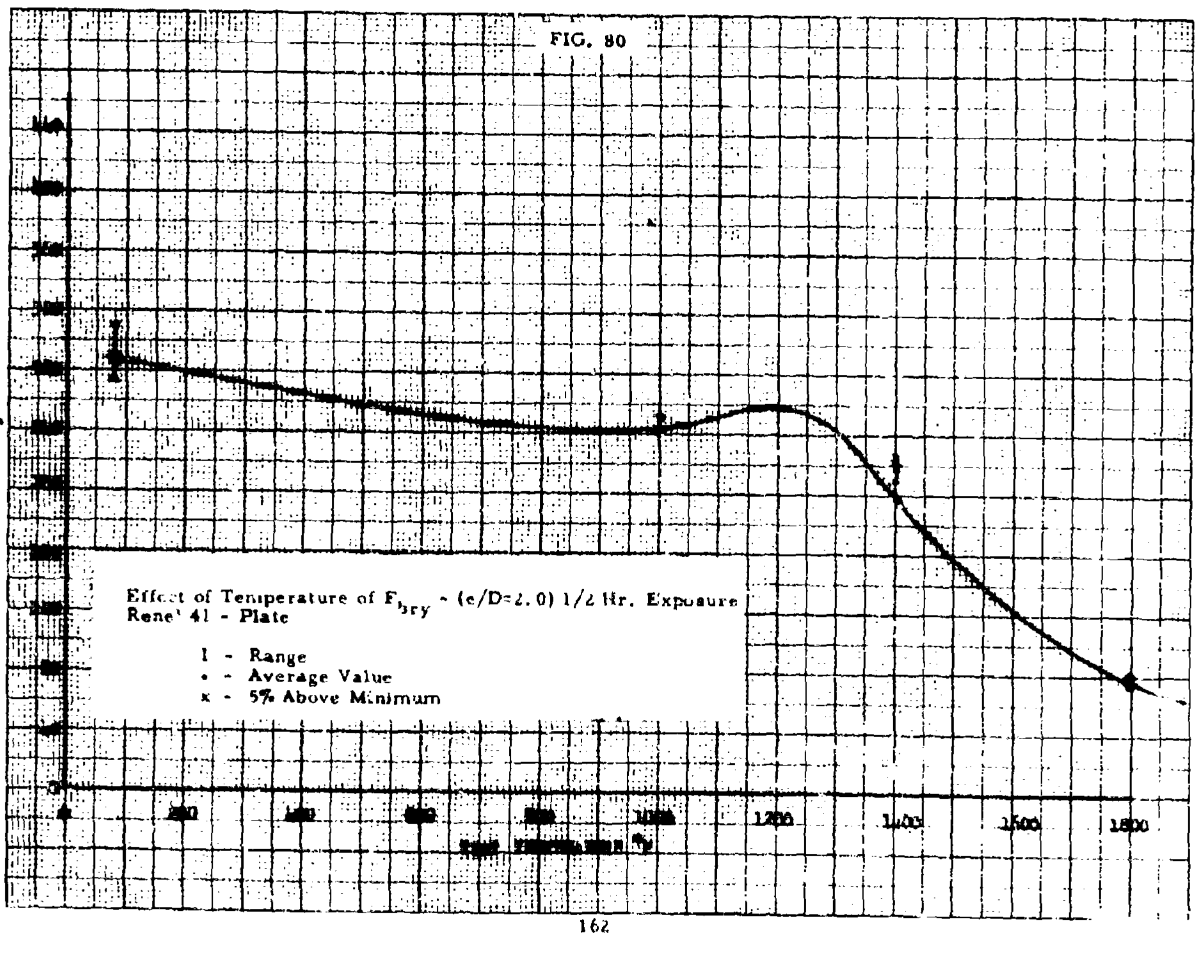

Effect of Temperature of F_{bry} - (e/D=2.0) 1/2 Hr. Exposure
Rene' 41 - Plate
I - Range
• - Average Value
x - 5% Above Minimum
F_{by} - KSI
1200
1400
1600
1800

FIG. 81

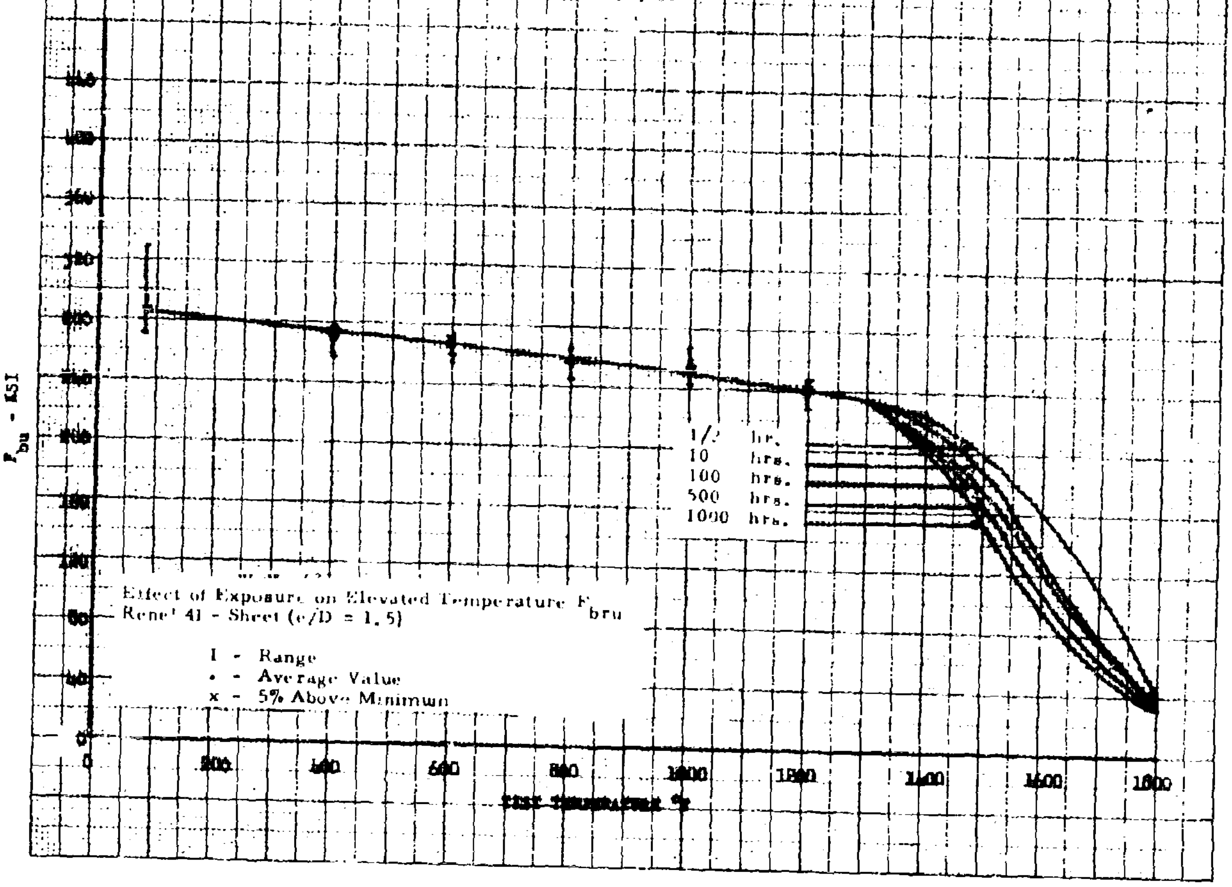
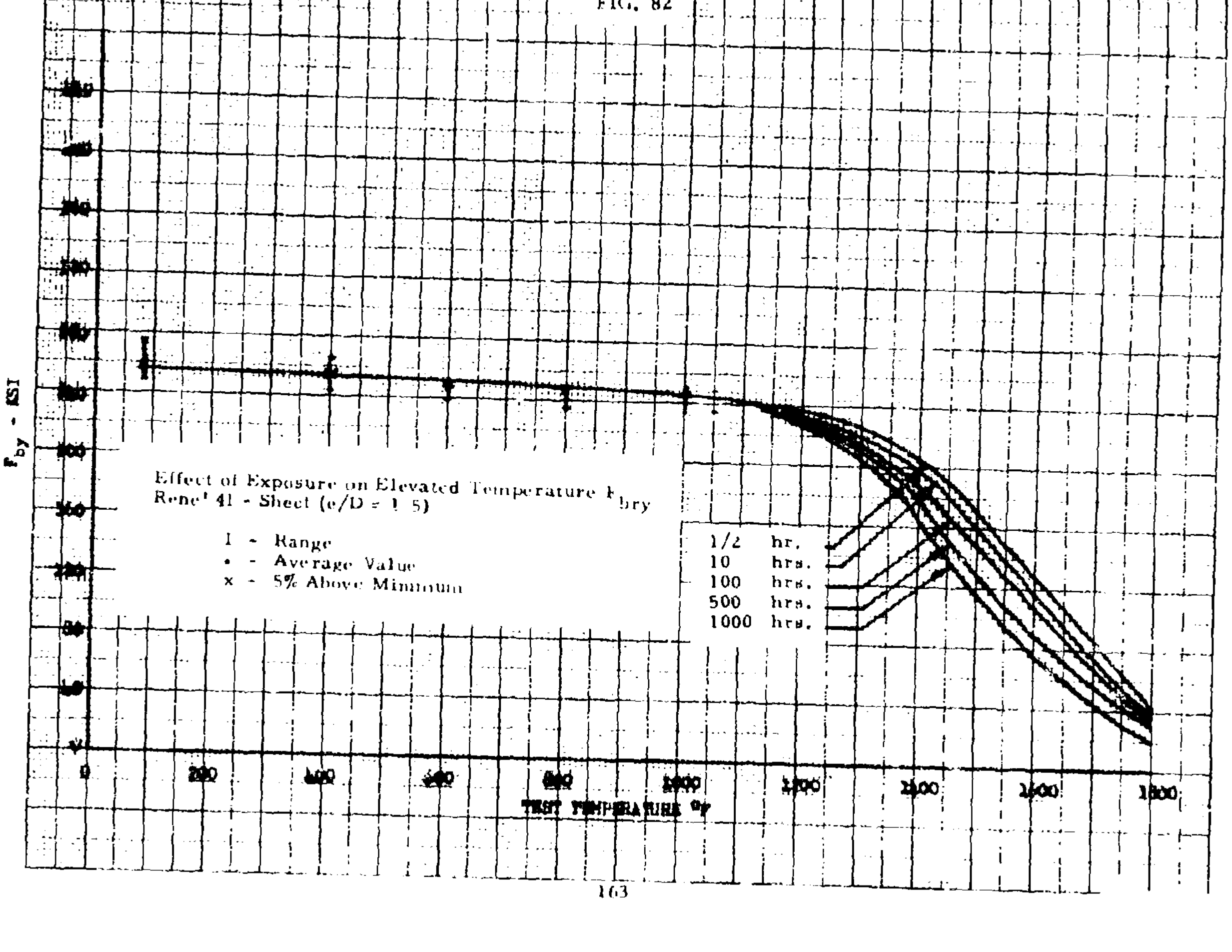

Effect of Exposure on Elevated Temperature F_{bru}
Rene' 41 - Sheet (e/D = 1.5)
I - Range
• - Average Value
x - 5% Above Minimum
1/2 hr.
10 hrs.
100 hrs.
500 hrs.
1000 hrs.
F_{bu} - KSI
TEST TEMPERATURE °F
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 82


Effect of Exposure on Elevated Temperature F_{bry}
Rene' 41 - Sheet (e/D = 1.5)
I - Range
• - Average Value
x - 5% Above Minimum
1/2 hr.
10 hrs.
100 hrs.
500 hrs.
1000 hrs.
F_{by} - KSI
TEST TEMPERATURE °F
0
200
400
600
800
1000
1200
1400
1600
1800

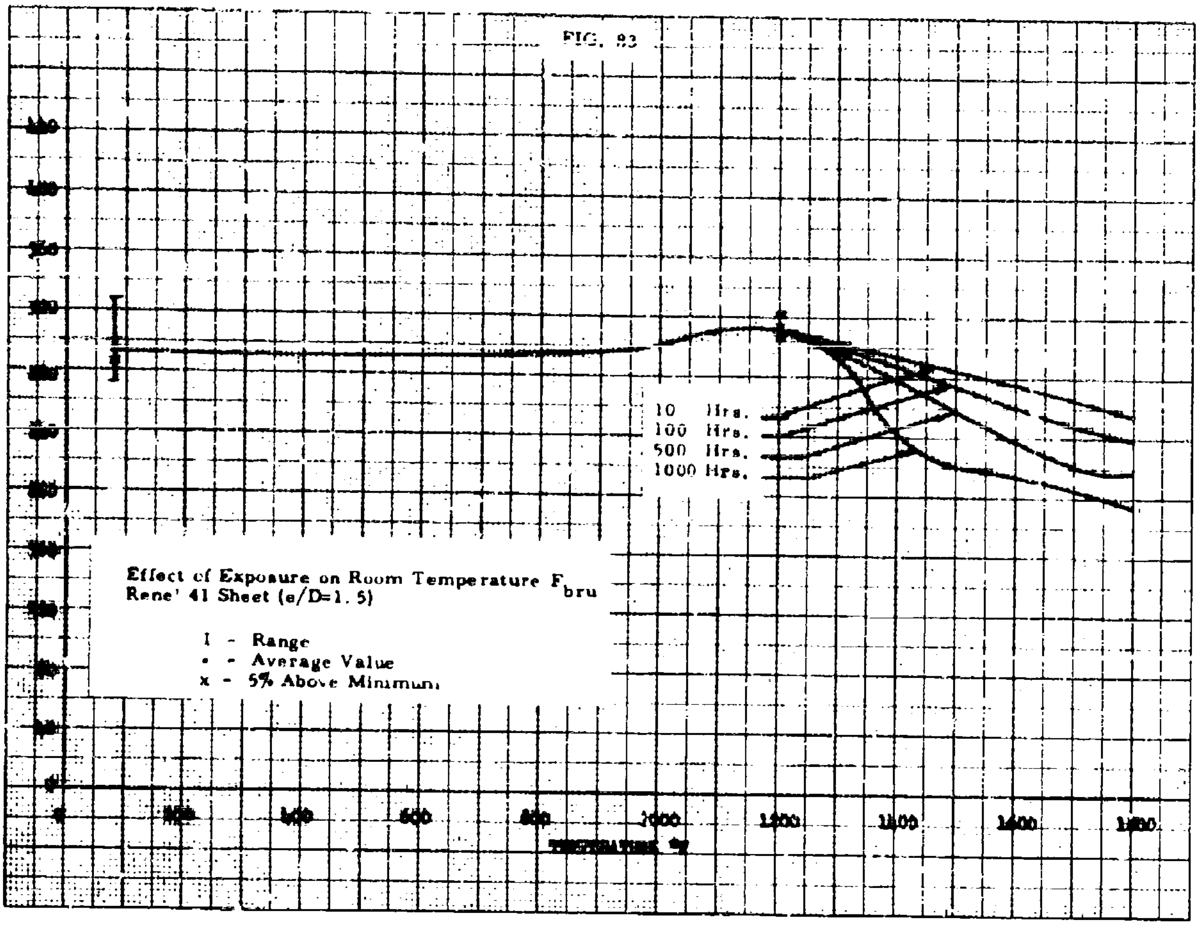

10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
Effect of Exposure on Room Temperature F_{bru}
Rene' 41 Sheet (e/D=1.5)
I - Range
• - Average Value
x - 5% Above Minimum

FIG. 83

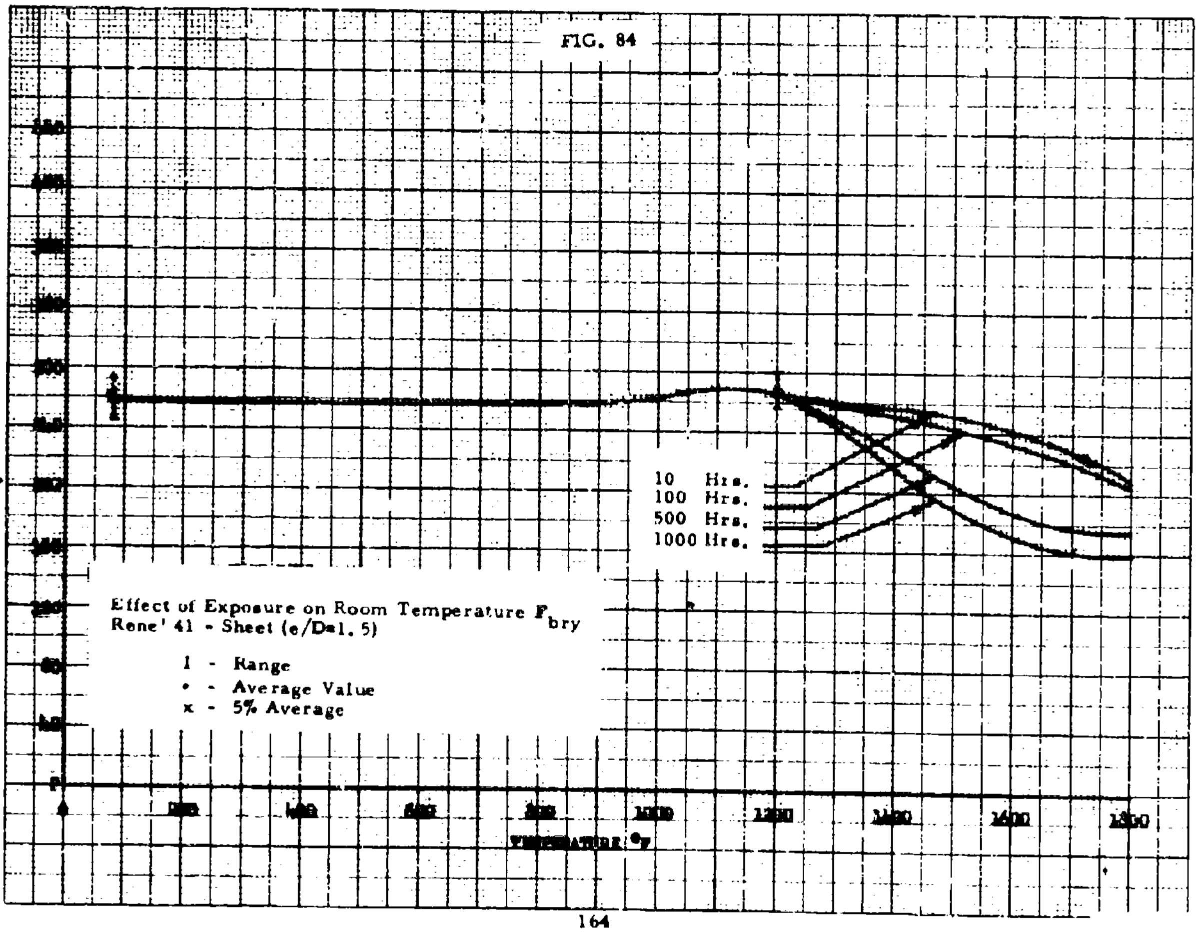
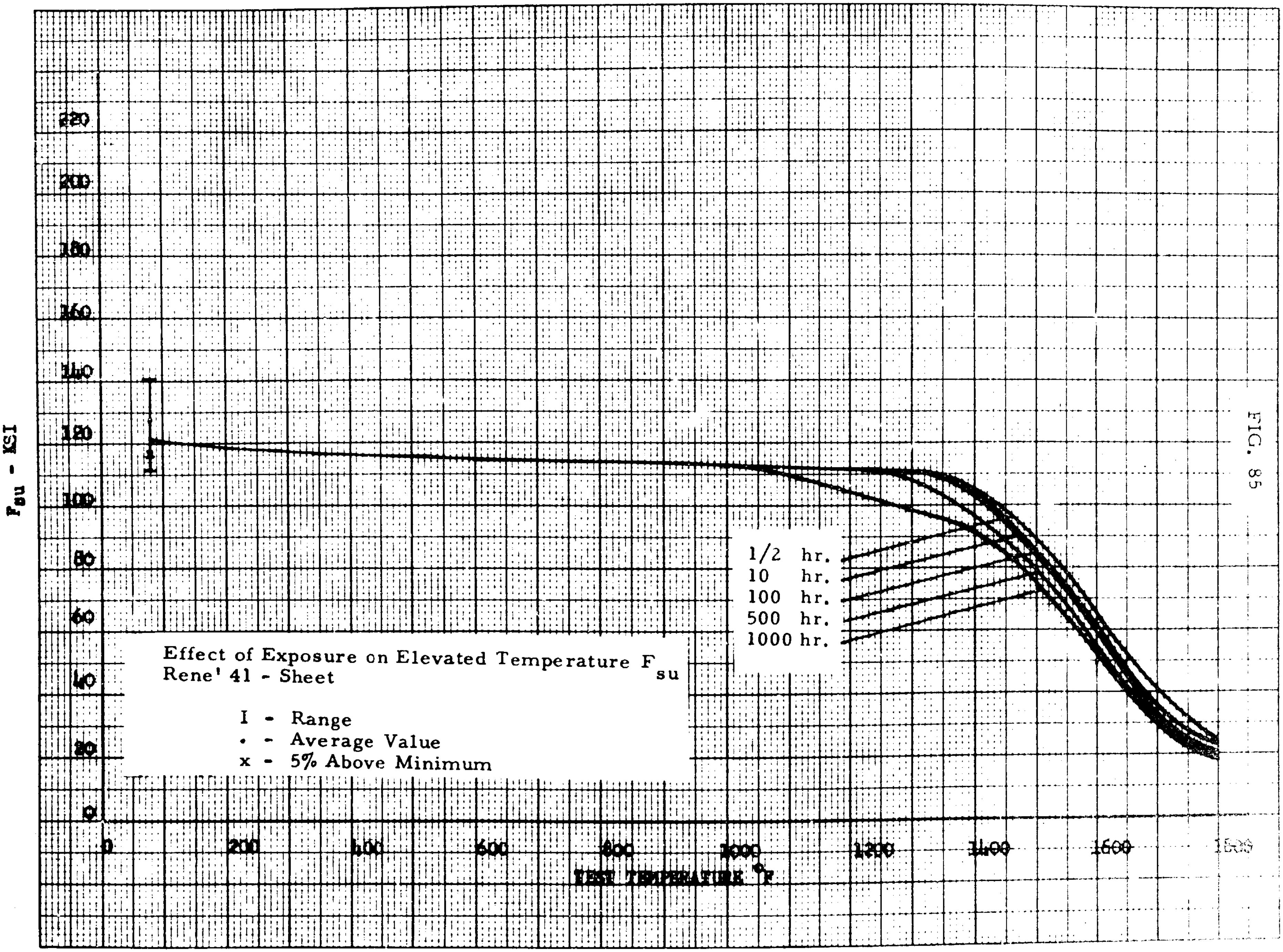

F_{bry} - KSI
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
Effect of Exposure on Room Temperature F_{bry}
Rene' 41 - Sheet (e/D=1.5)
I - Range
• - Average Value
x - 5% Average
1200
1800

FIG. 84

SECTION VII

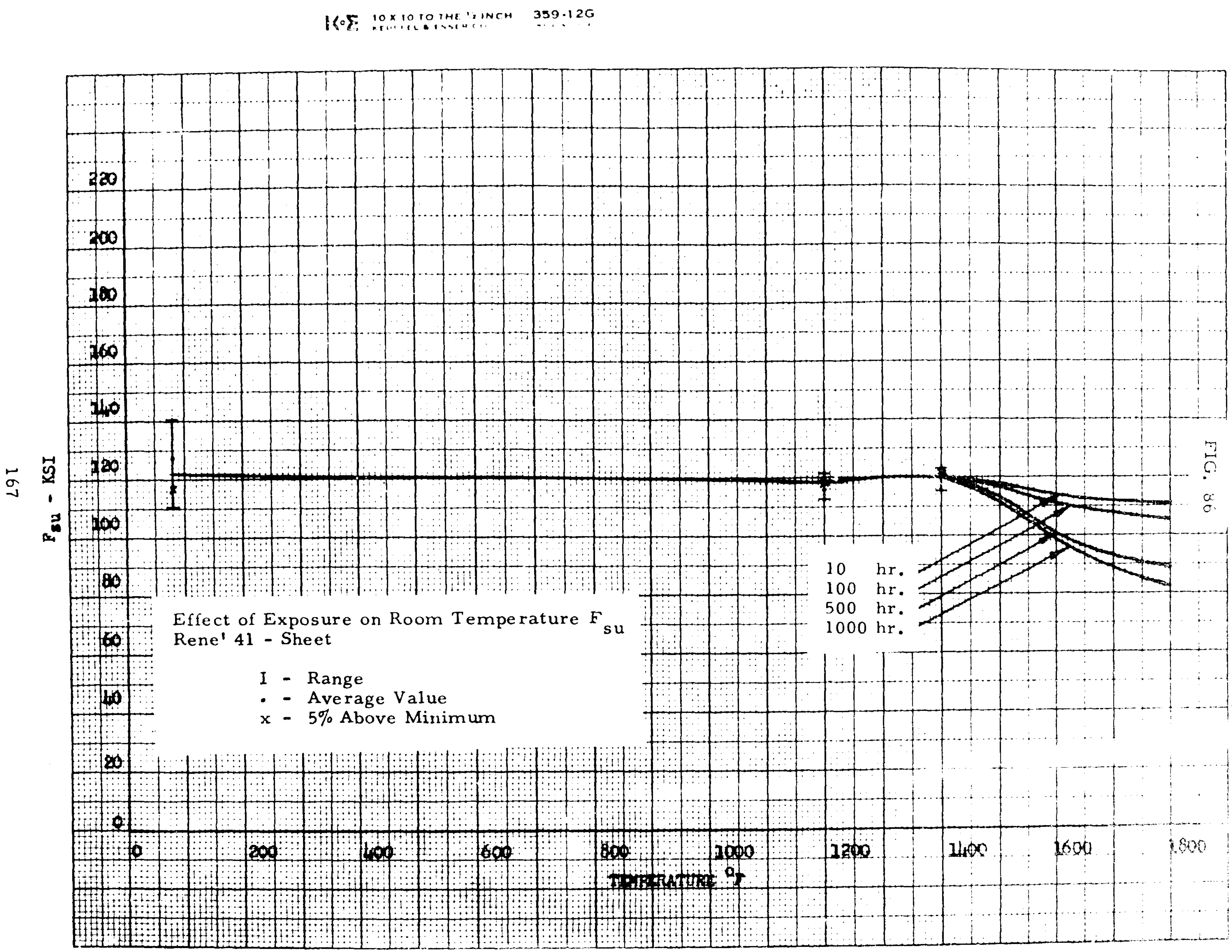
SECTION 7.1.4 SHEAR

FIG. 85



Effect of Exposure on Elevated Temperature F_{su}
Rene' 41 - Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1/2 hr.
10 hr.
100 hr.
500 hr.
1000 hr.
F_{su} - KSI
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
TEST TEMPERATURE °F

FIG. 86



K&E 10 X 10 TO THE 1/2 INCH 359-12G
Effect of Exposure on Room Temperature F_{su}
Rene' 41 - Sheet
I - Range
. - Average Value
x - 5% Above Minimum
10 hr.
100 hr.
500 hr.
1000 hr.
220
200
180
160
140
120
100
80
60
40
20
0
F_{su} - KSI
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE °F

SECTION VII

SECTION 7.1.5 CREEP

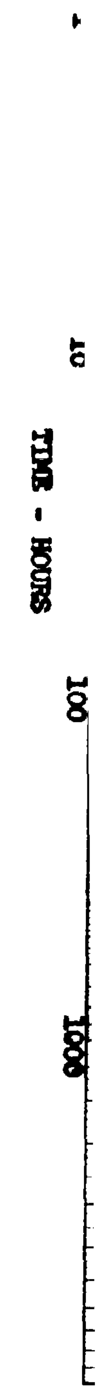
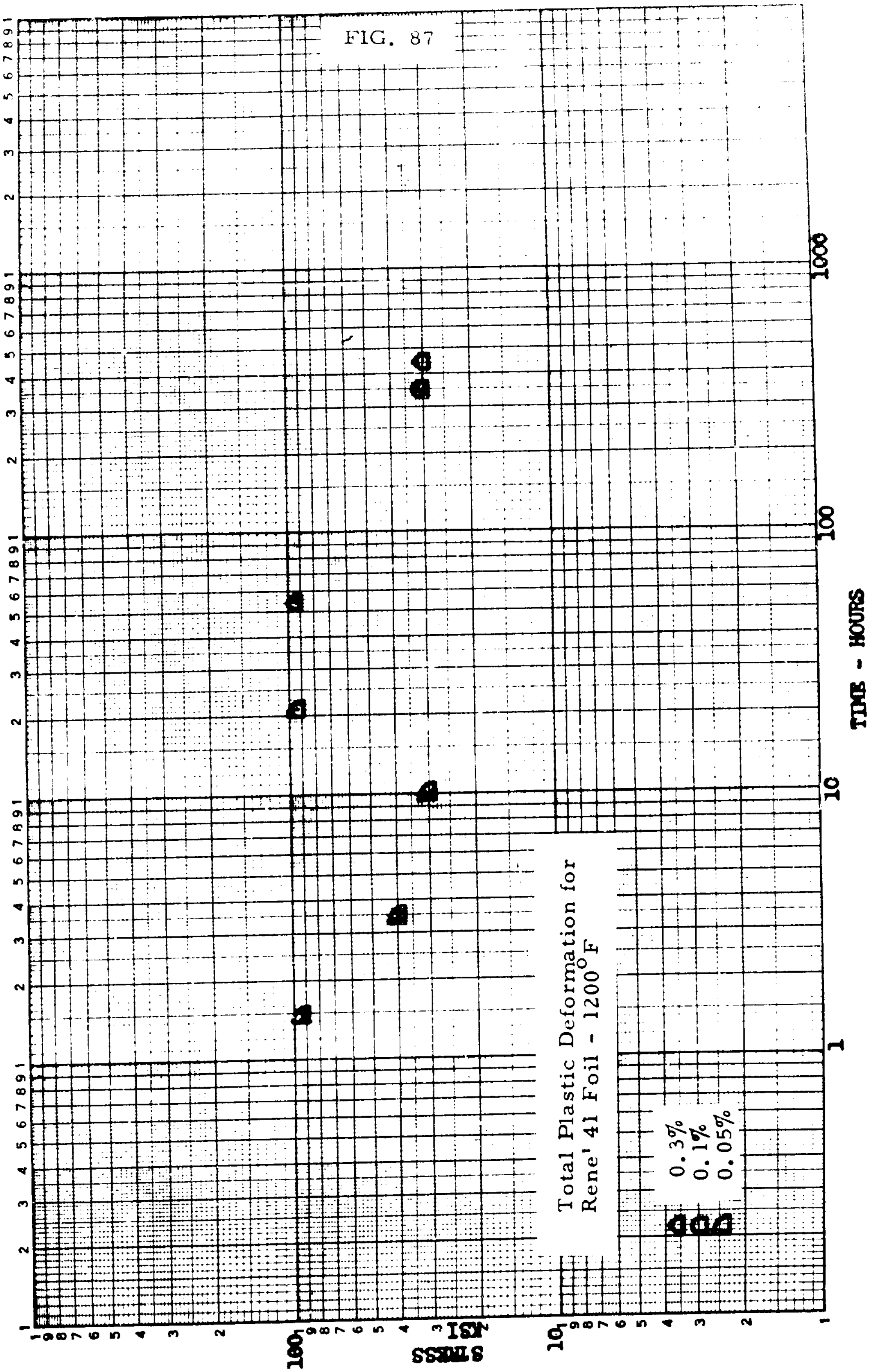
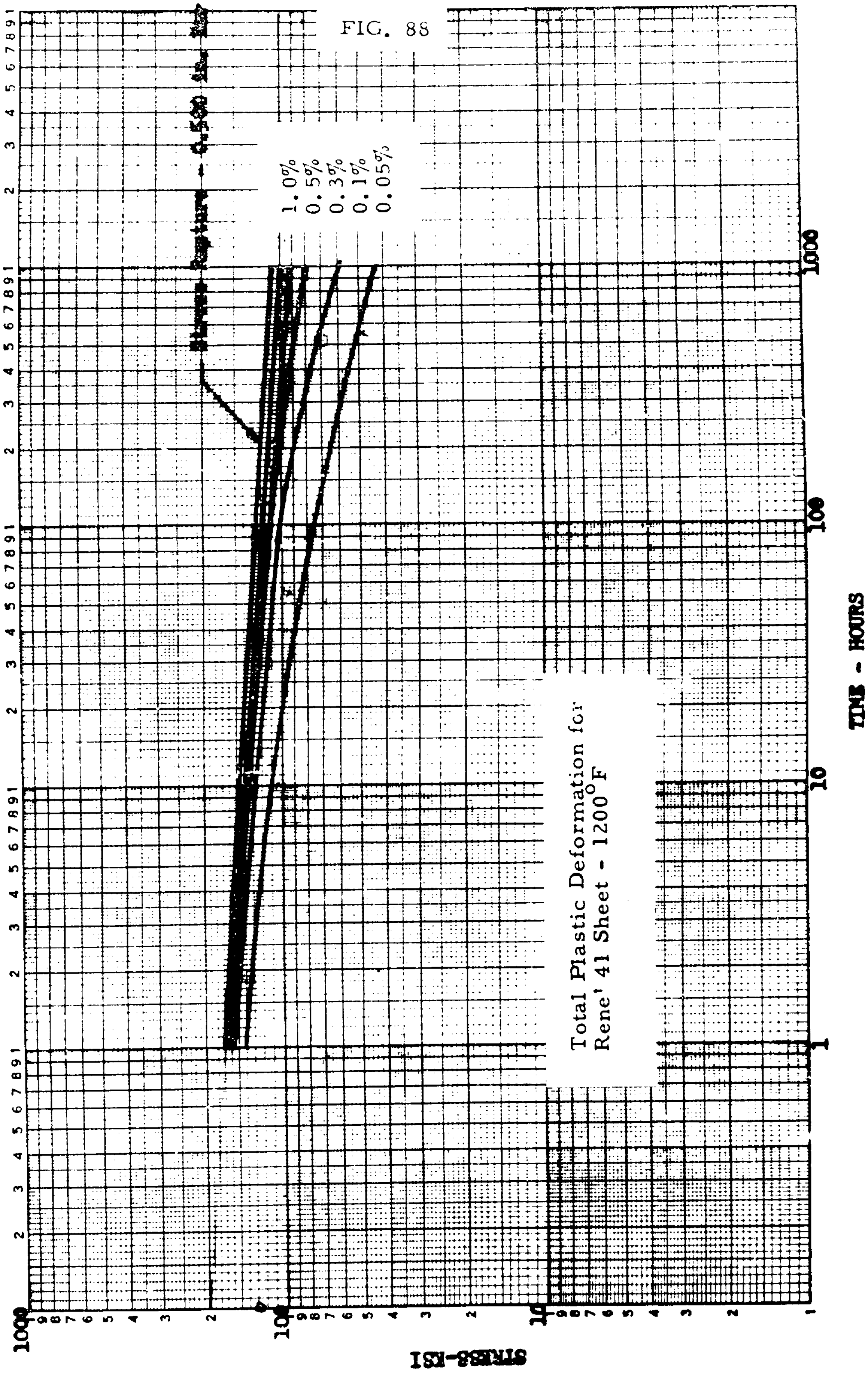


FIG. 87



Total Plastic Deformation for
Rene' 41 Foil - 1200°F
0.3%
0.1%
0.05%
TIME - HOURS
1
10
100
1000
STRESS
KSI
100
10

FIG. 88



Total Plastic Deformation for
Rene' 41 Sheet - 1200^{o}F

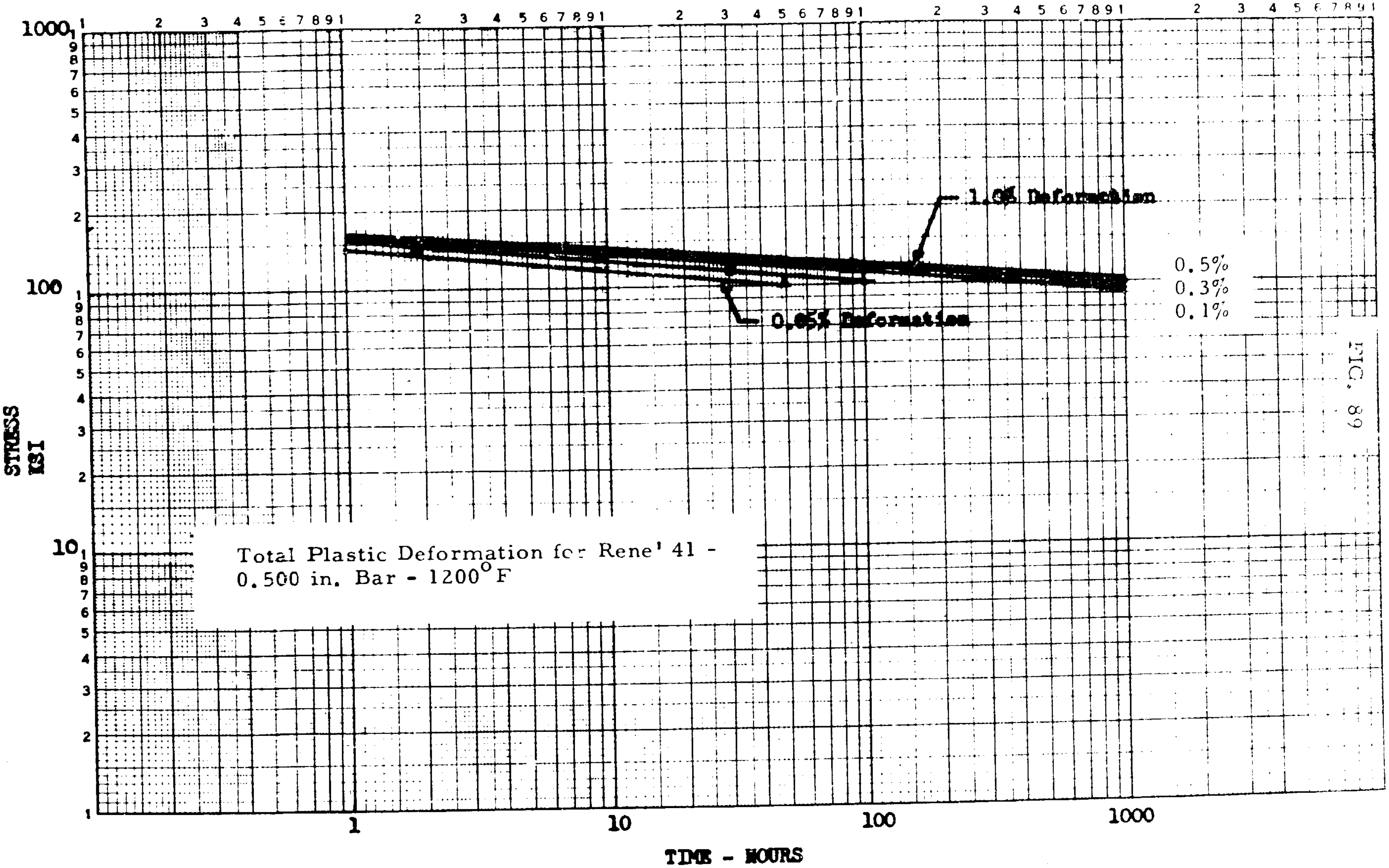
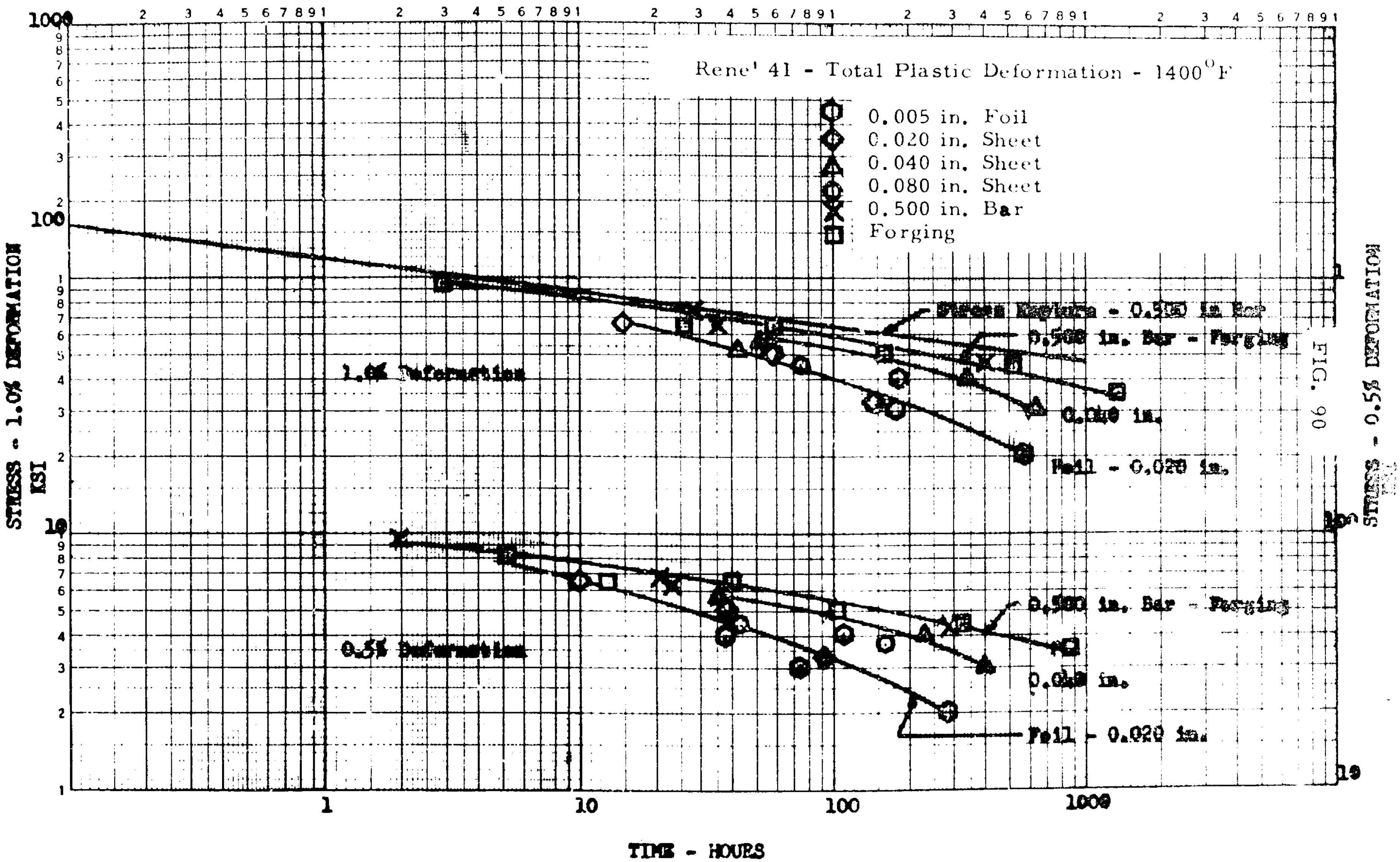


FIG. 89

Total Plastic Deformation for Rene' 41 - 0.500 in. Bar - 1200^{o}F

FIG. 90


Rene' 41 - Total Plastic Deformation - 1400°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
1.0% Deformation
0.5% Deformation
0.500 in. Bar - Forging
0.040 in.
Foil - 0.020 in.
STRESS - 1.0% DEFORMATION
KSI
STRESS - 0.5% DEFORMATION
TIME - HOURS
1
10
100
1000

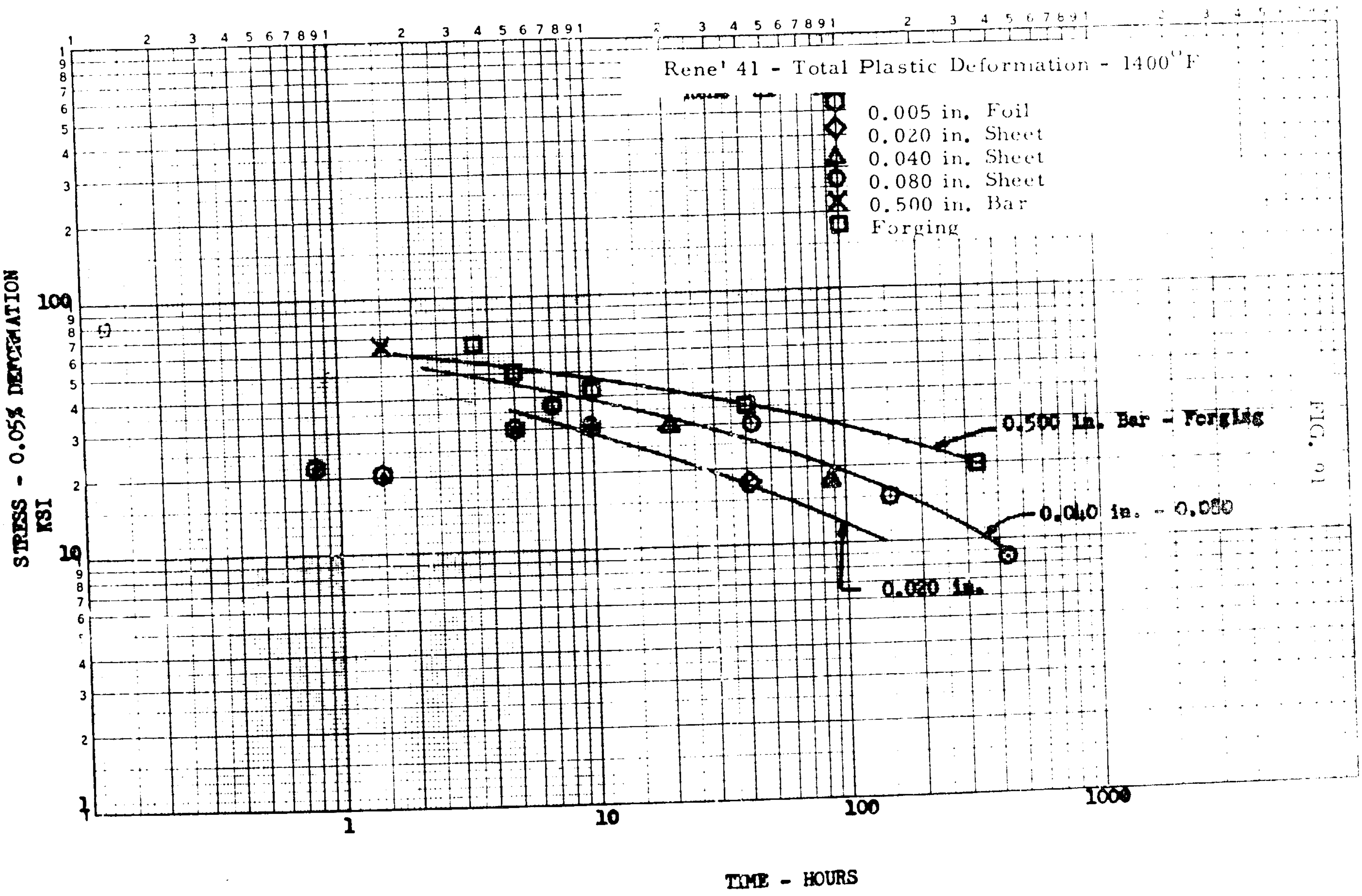
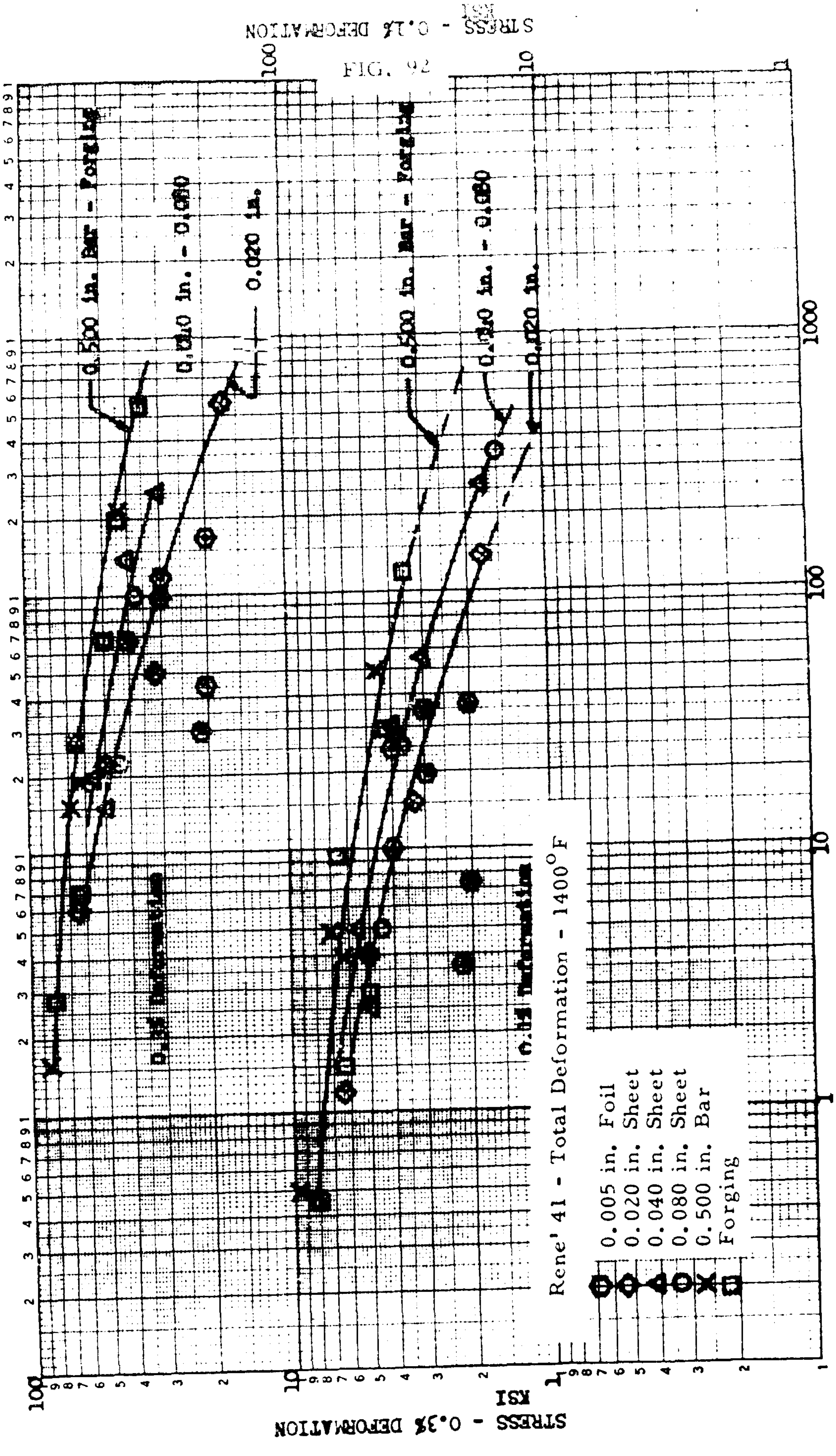

Rene' 41 - Total Plastic Deformation - 1400°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
0.500 in. Bar - Forging
0.040 in. - 0.080
0.020 in.
STRESS - 0.05% DEFORMATION
KSI
TIME - HOURS

FIG. 91



STRESS - 0.1% DEFORMATION
KSI
0.500 in. Bar - Forging
0.040 in. - 0.080
0.020 in.
0.1% Deformation
0.3% Deformation
TIME - HOURS
Rene' 41 - Total Deformation - 1400°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
STRESS - 0.3% DEFORMATION
KSI

FIG. 92

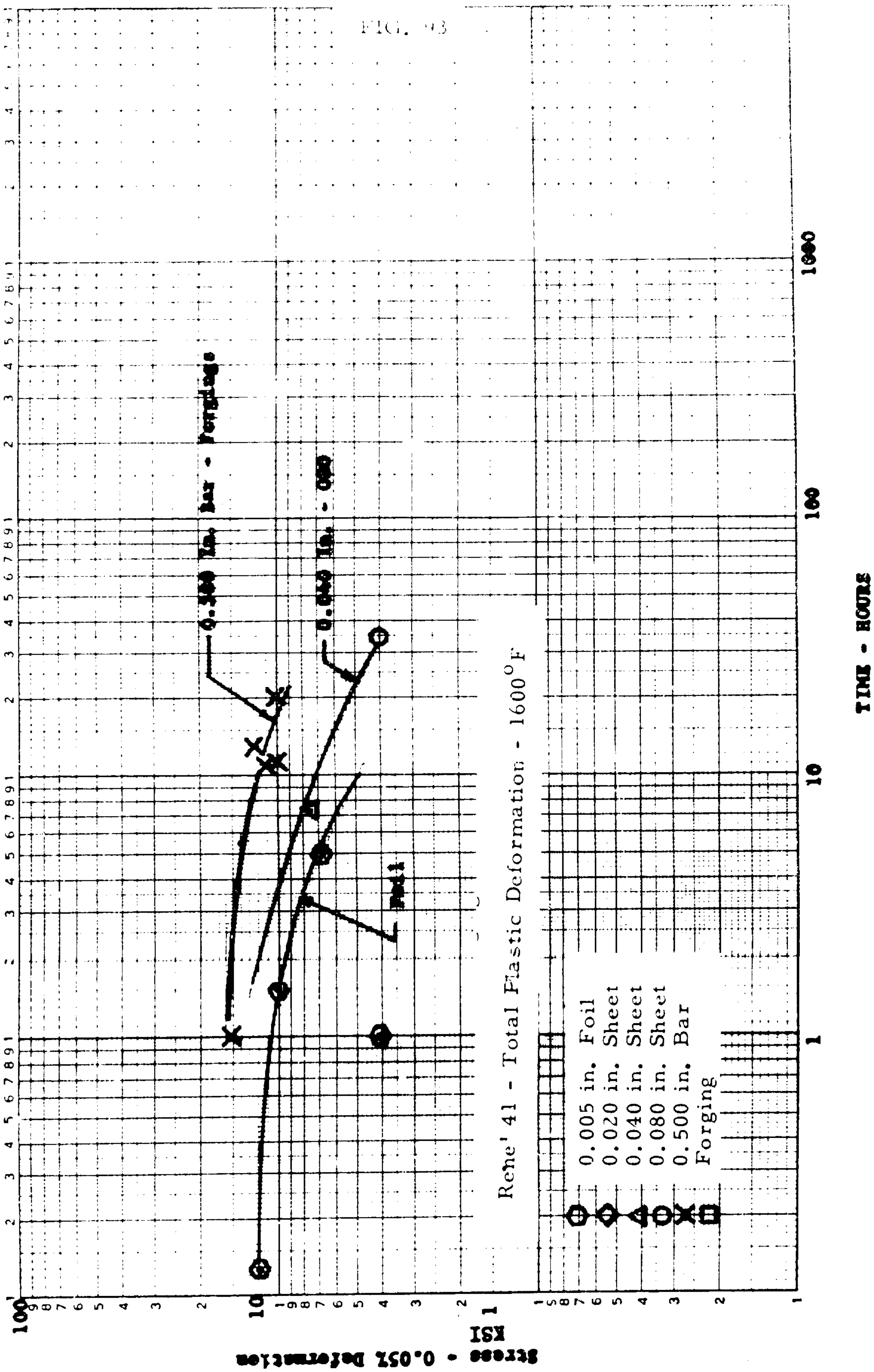
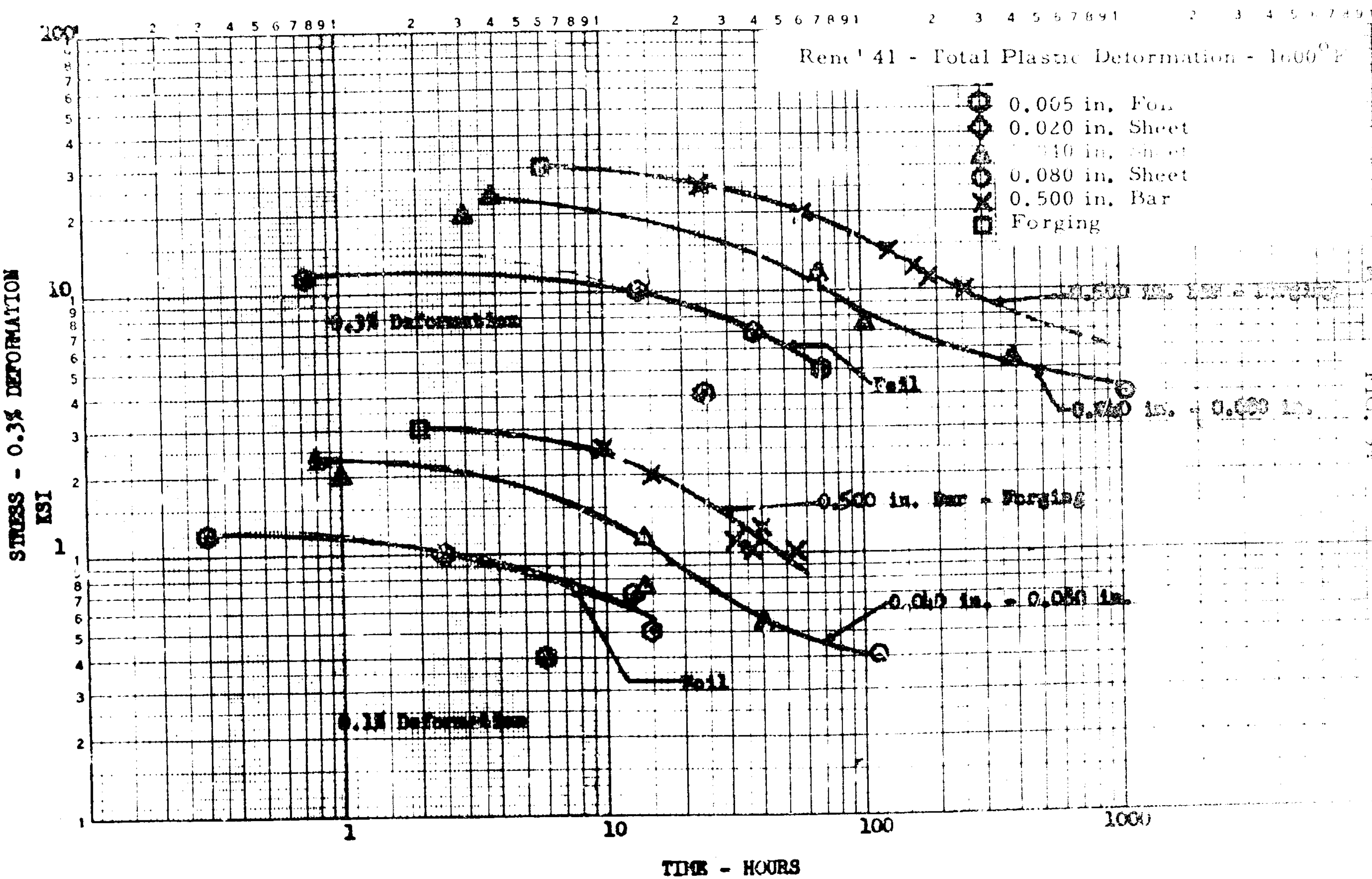
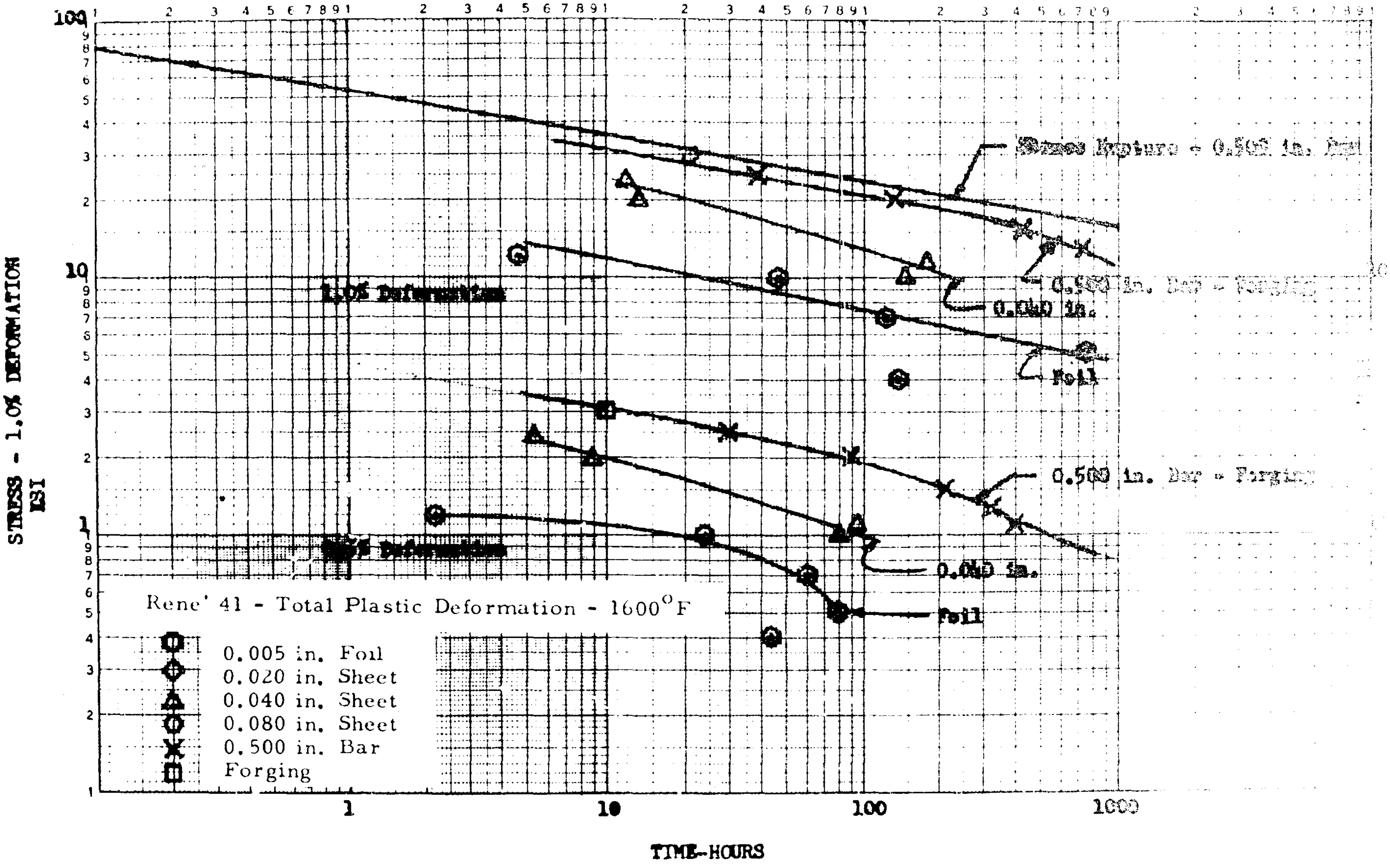


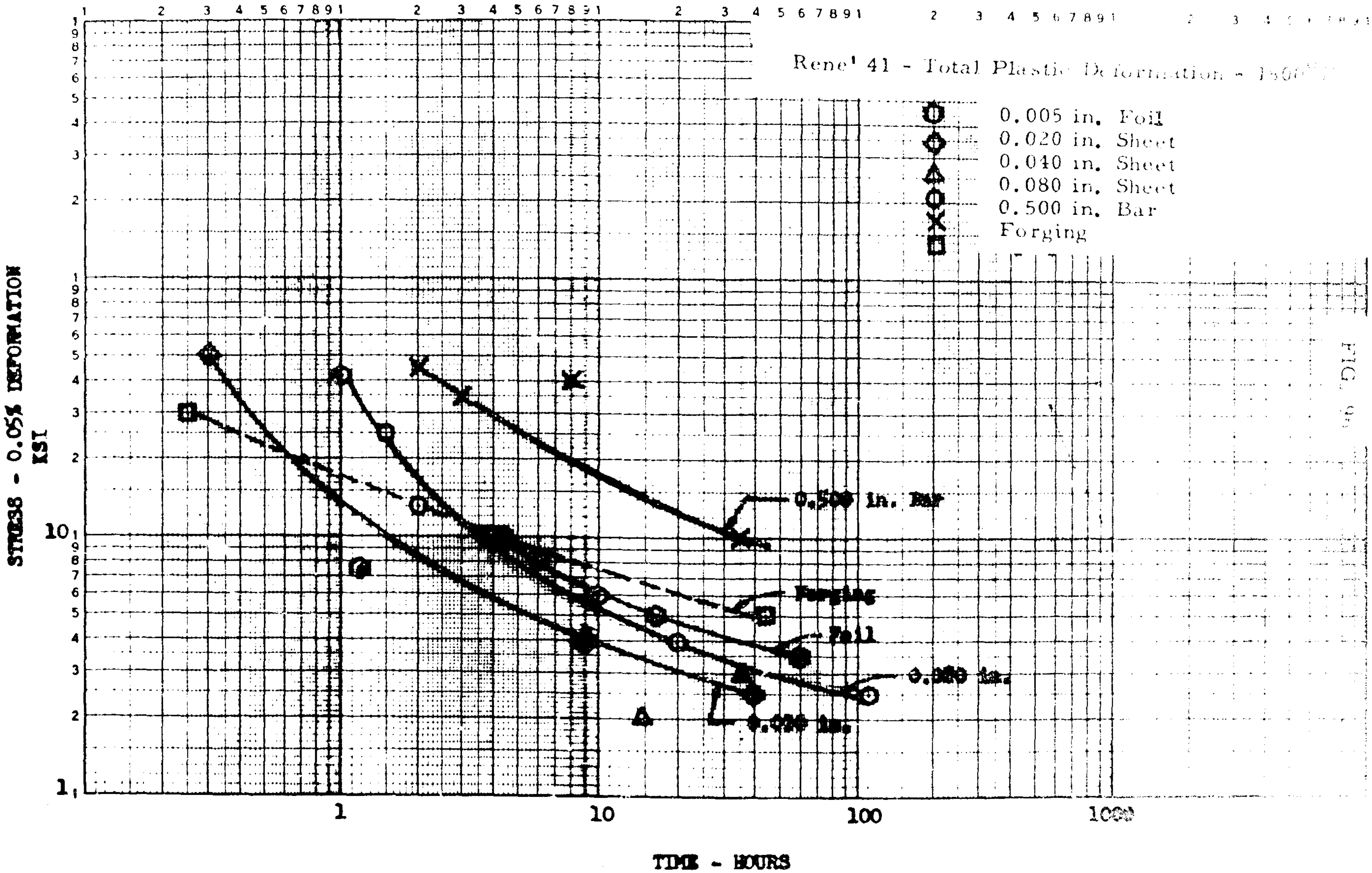
FIG. 93
Rene' 41 - Total Plastic Deformation - 1600°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
0.500 in. Bar - Forgings
0.040 in. - 080
Foil
TIME - HOURS
Stress - 0.05% Deformation
KSI

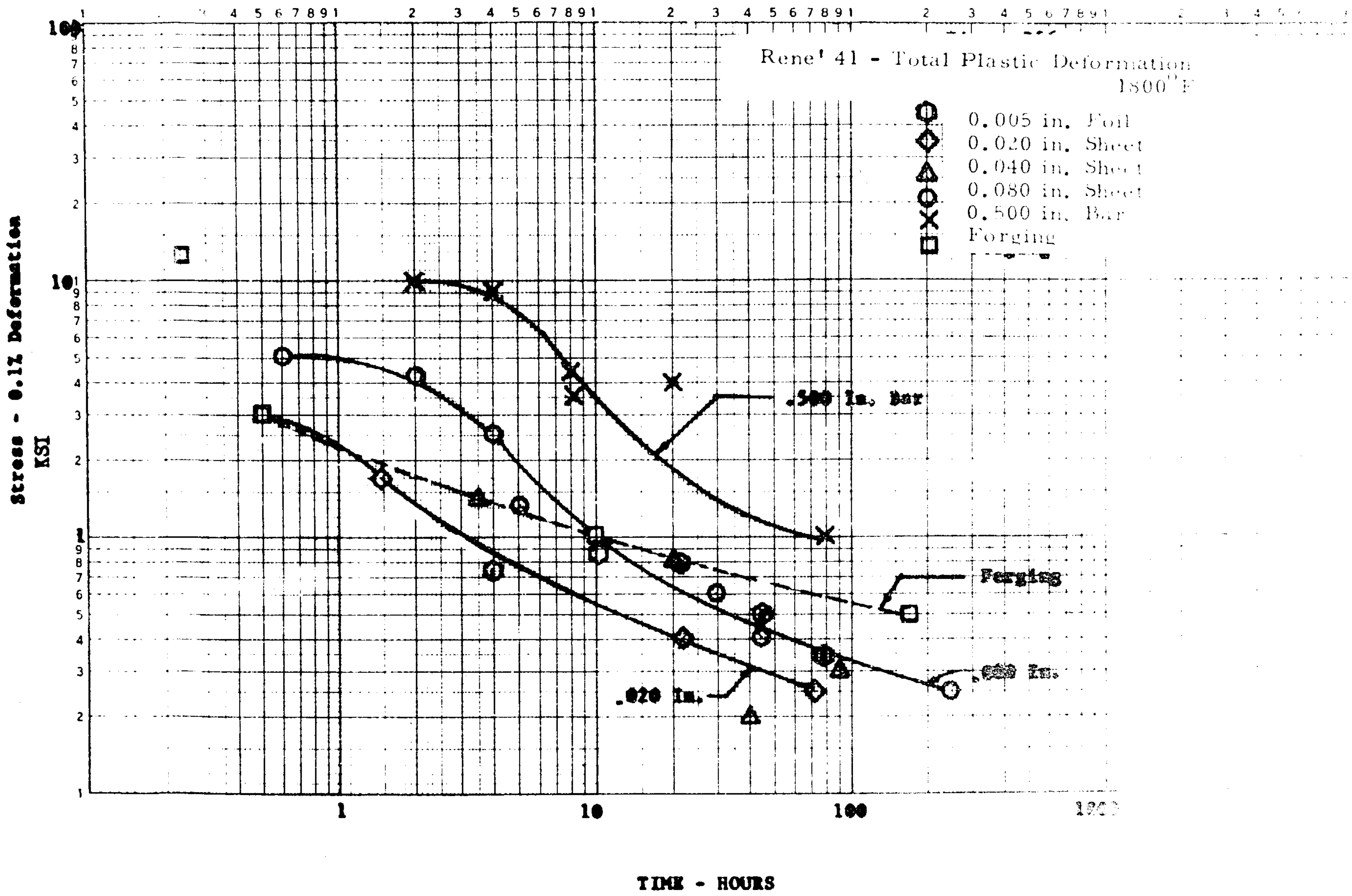
FIG. 94


Rene' 41 - Total Plastic Deformation - 1600°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
0.3% Deformation
0.1% Deformation
Foil
0.500 in. Bar - Forging
0.040 in. - 0.080 in.
STRESS - 0.3% DEFORMATION KSI
TIME - HOURS



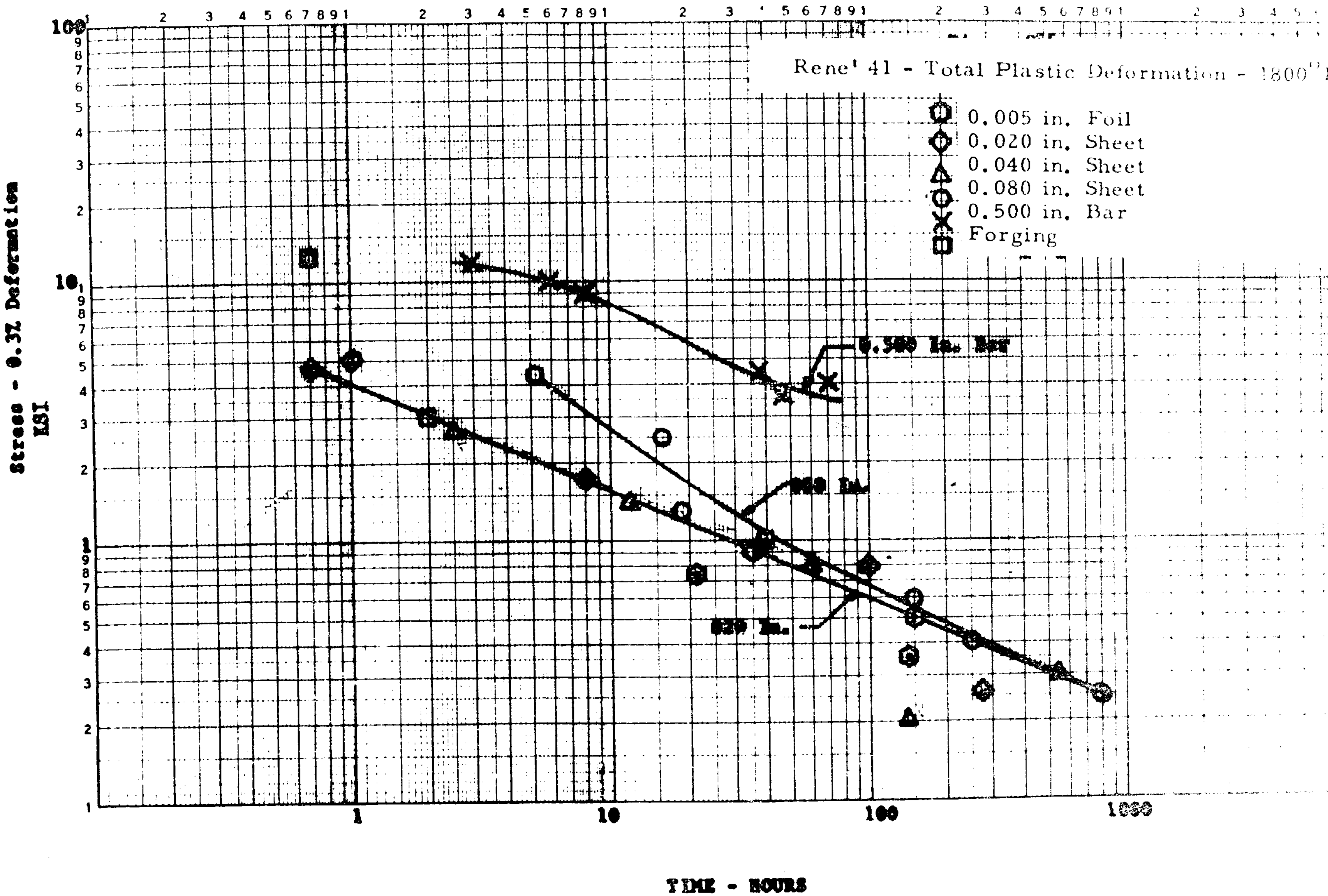
Rene' 41 - Total Plastic Deformation - 1600°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
1.0% Deformation
Stress Rupture - 0.500 in. Bar
0.500 in. Bar - Forging
0.040 in.
Foil
STRESS - 1.0% DEFORMATION
KSI
TIME-HOURS


Rene' 41 - Total Plastic Deformation
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
0.500 in. Bar
Forging
Foil
STRESS - 0.05% DEFORMATION KSI
TIME - HOURS
1
10
100
1000

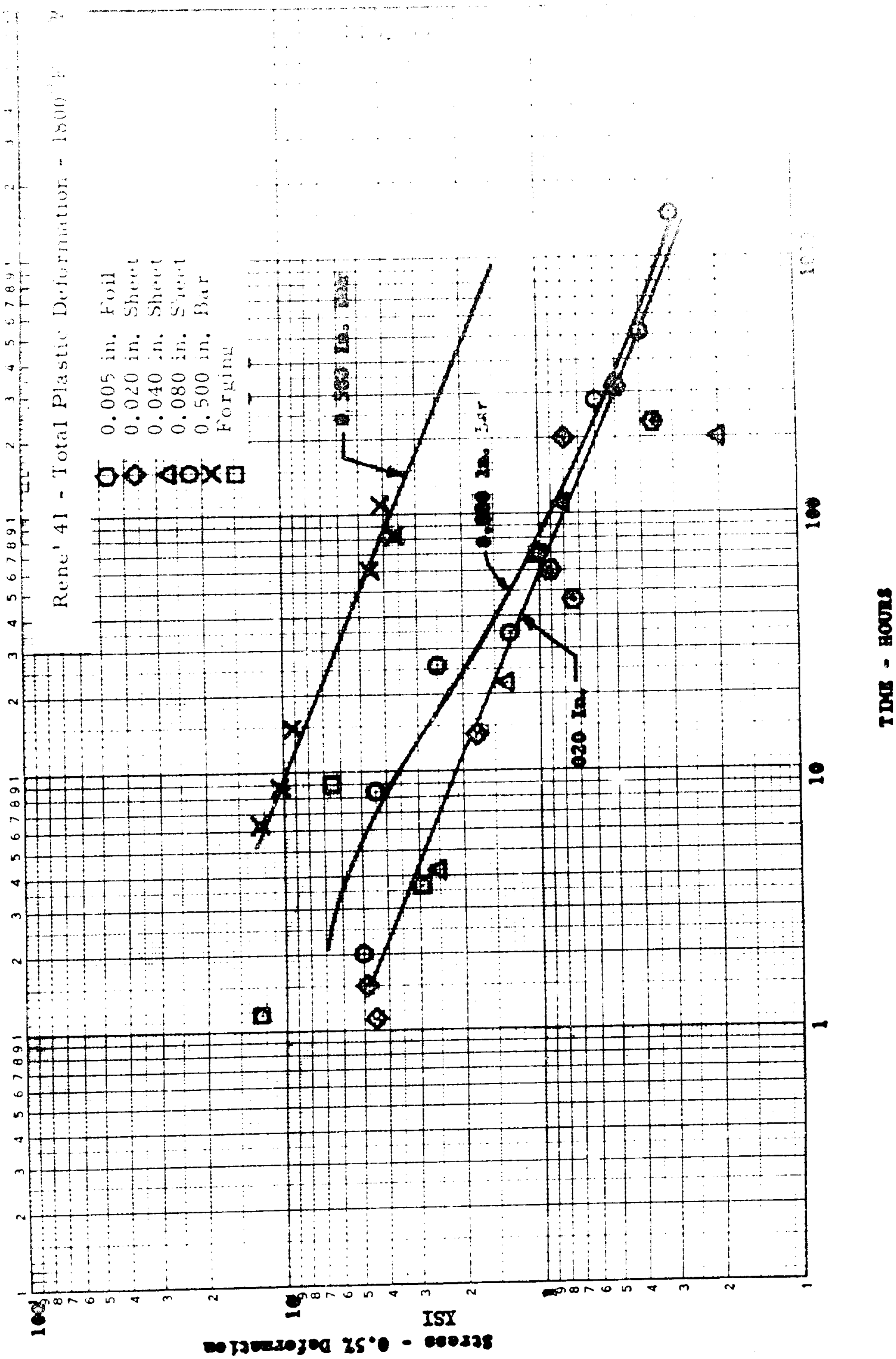


Rene' 41 - Total Plastic Deformation
1800°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
.500 In. Bar
Forging
.020 In.
Stress - 0.1% Deformation
KSI
TIME - HOURS
1
10
100

FIG. 98

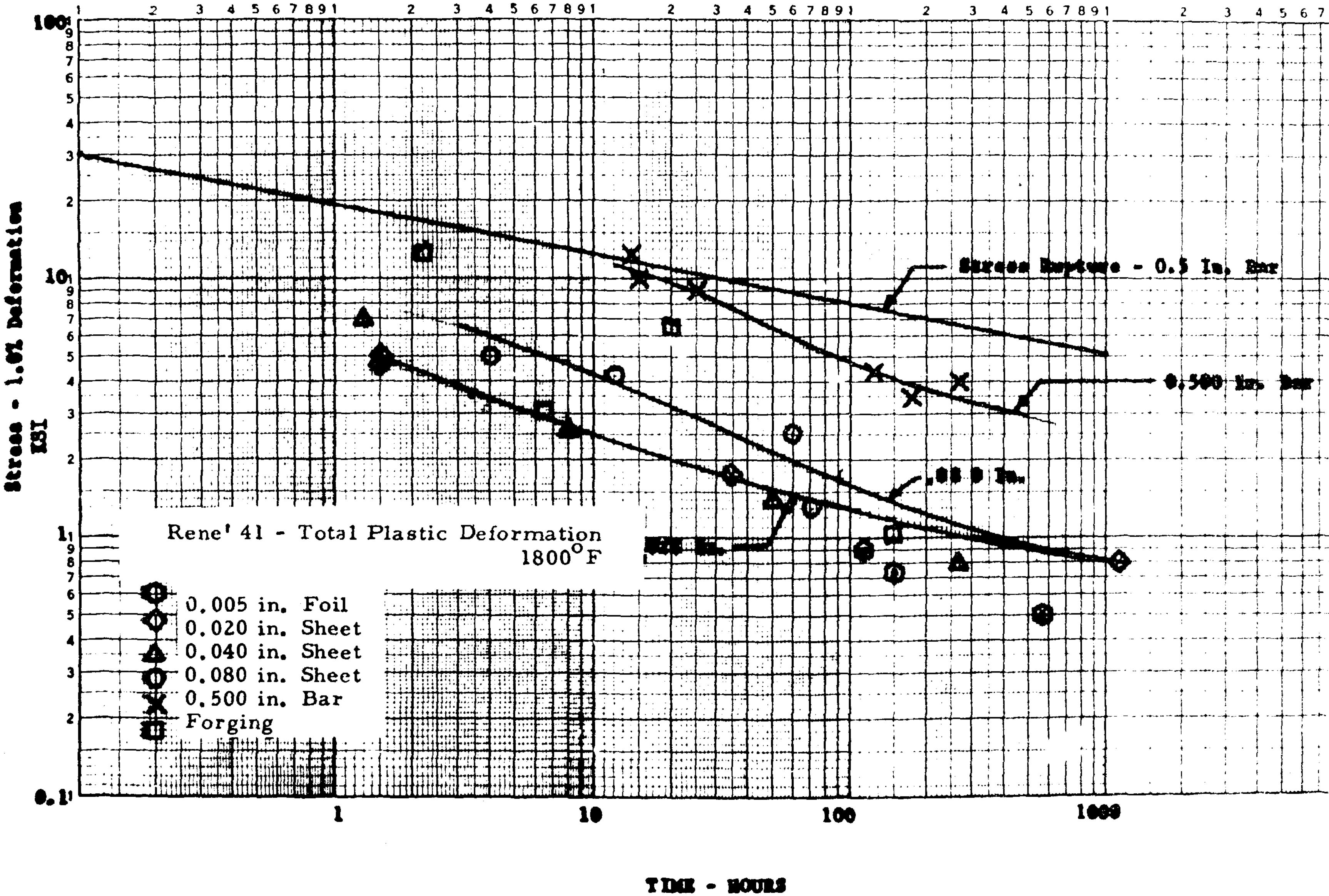


Rene' 41 - Total Plastic Deformation - 1800°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
0.500 In. Bar
Stress - 0.3% Deformation
KSI
TIME - HOURS



Rene' 41 - Total Plastic Deformation - 1800 °F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
020 In.
TIME - HOURS
Stress - 0.5% Deformation
KSI

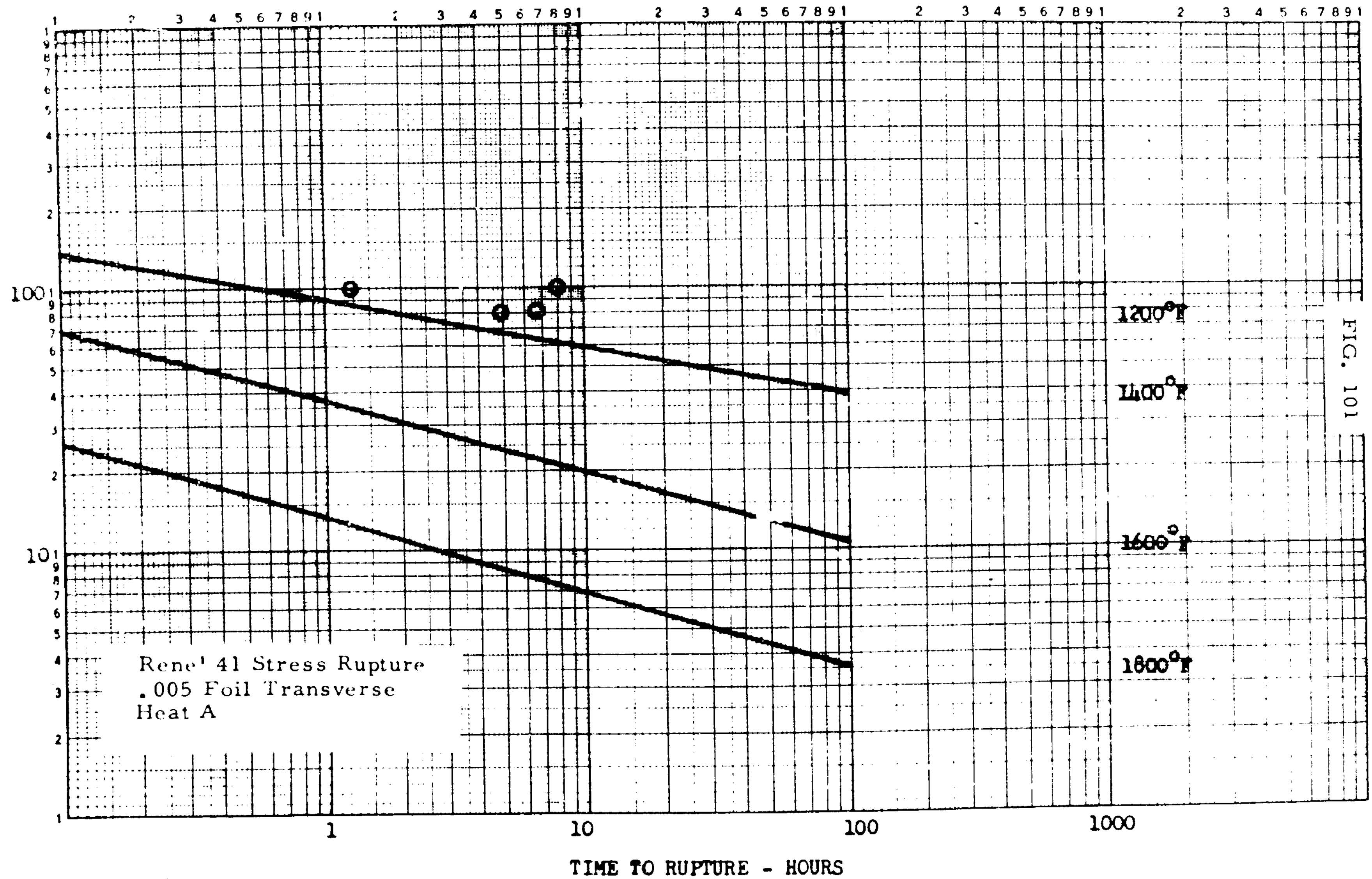
FIG. 100


Rene' 41 - Total Plastic Deformation
1800°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
Stress Rupture - 0.5 In. Bar
0.500 In. Bar
Stress - 1.0% Deformation
KSI
TIME - HOURS
0.1
1
10
100
1000

SECTION VII

SECTION 7.1.6 STRESS RUPTURE

FIG. 101



Rene' 41 Stress Rupture
.005 Foil Transverse
Heat A
1200°F
1400°F
1600°F
1800°F
STRESS - KSI
TIME TO RUPTURE - HOURS
1
10
100
1000

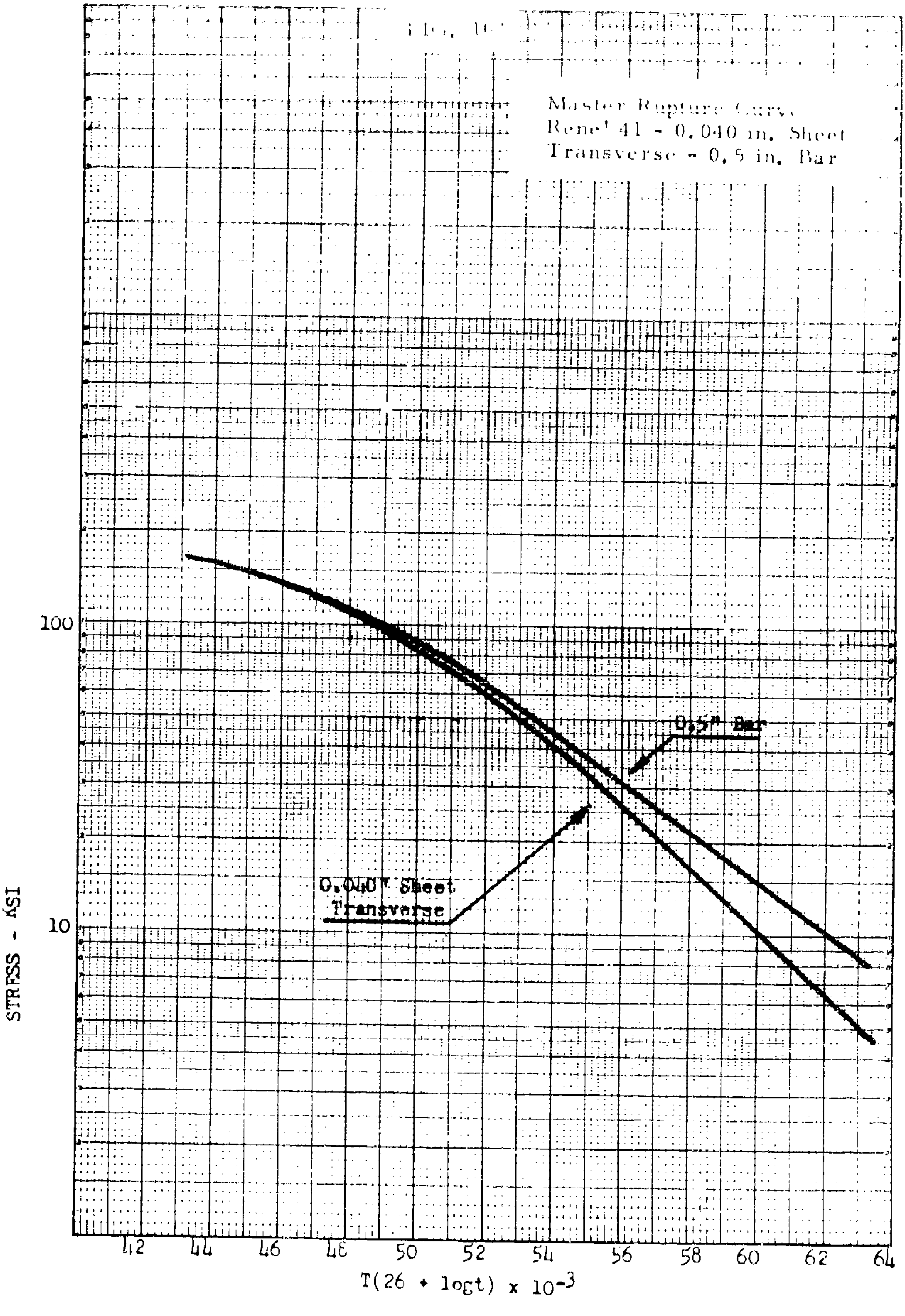
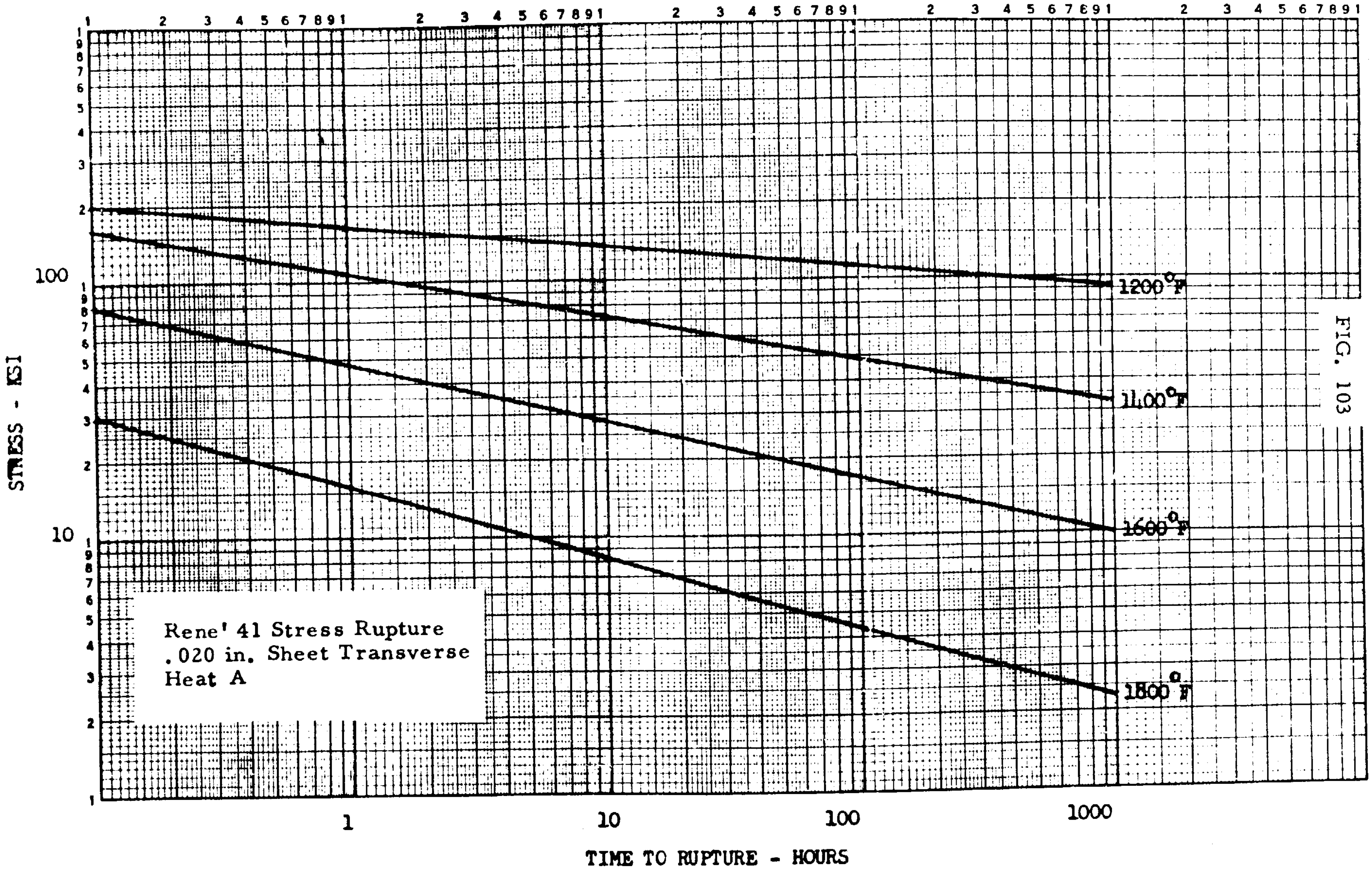
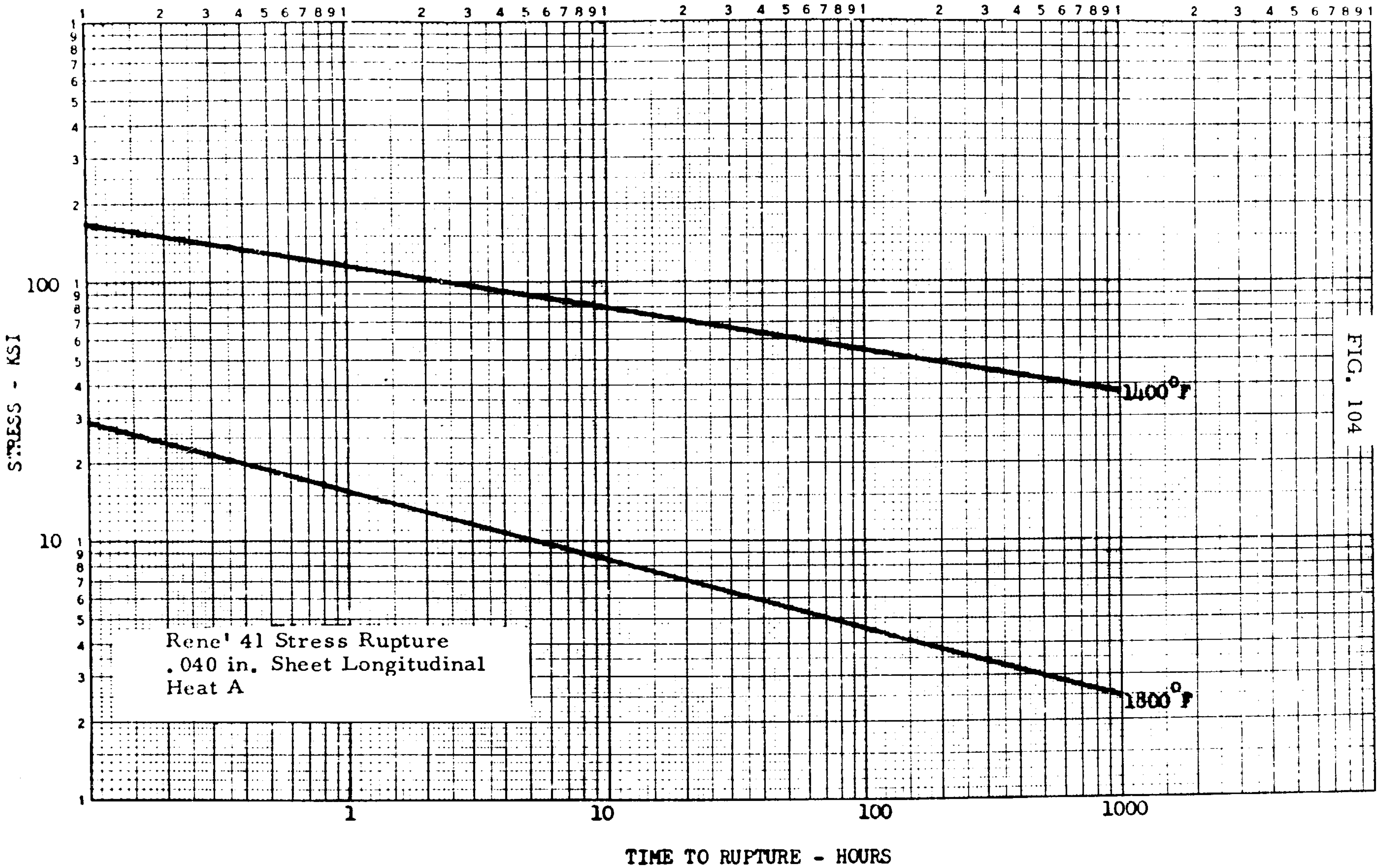

Master Rupture Curve
Rene' 41 - 0.040 in. Sheet
Transverse - 0.5 in. Bar
0.5" Bar
0.040" Sheet
Transverse
STRESS - KSI
100
10
42
44
46
48
50
52
54
56
58
60
62
64
T(26 + logt) x 10-3

FIG. 103



Rene' 41 Stress Rupture
.020 in. Sheet Transverse
Heat A
1200°F
1100°F
1600°F
1800°F
STRESS - KSI
TIME TO RUPTURE - HOURS

FIG. 104



Rene' 41 Stress Rupture
.040 in. Sheet Longitudinal
Heat A
1400°F
1800°F
STRESS - KSI
100
10
TIME TO RUPTURE - HOURS
1
10
100
1000

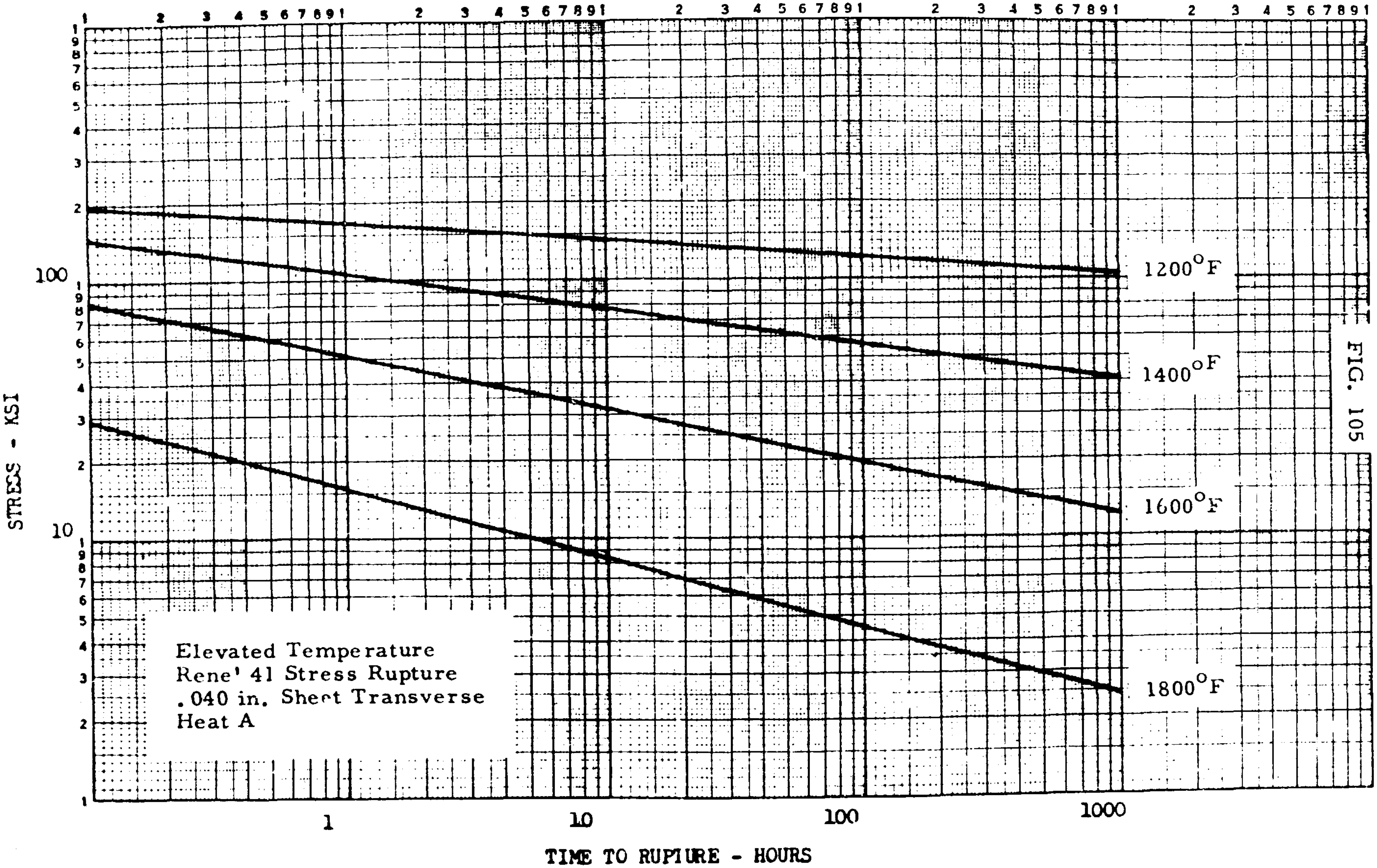
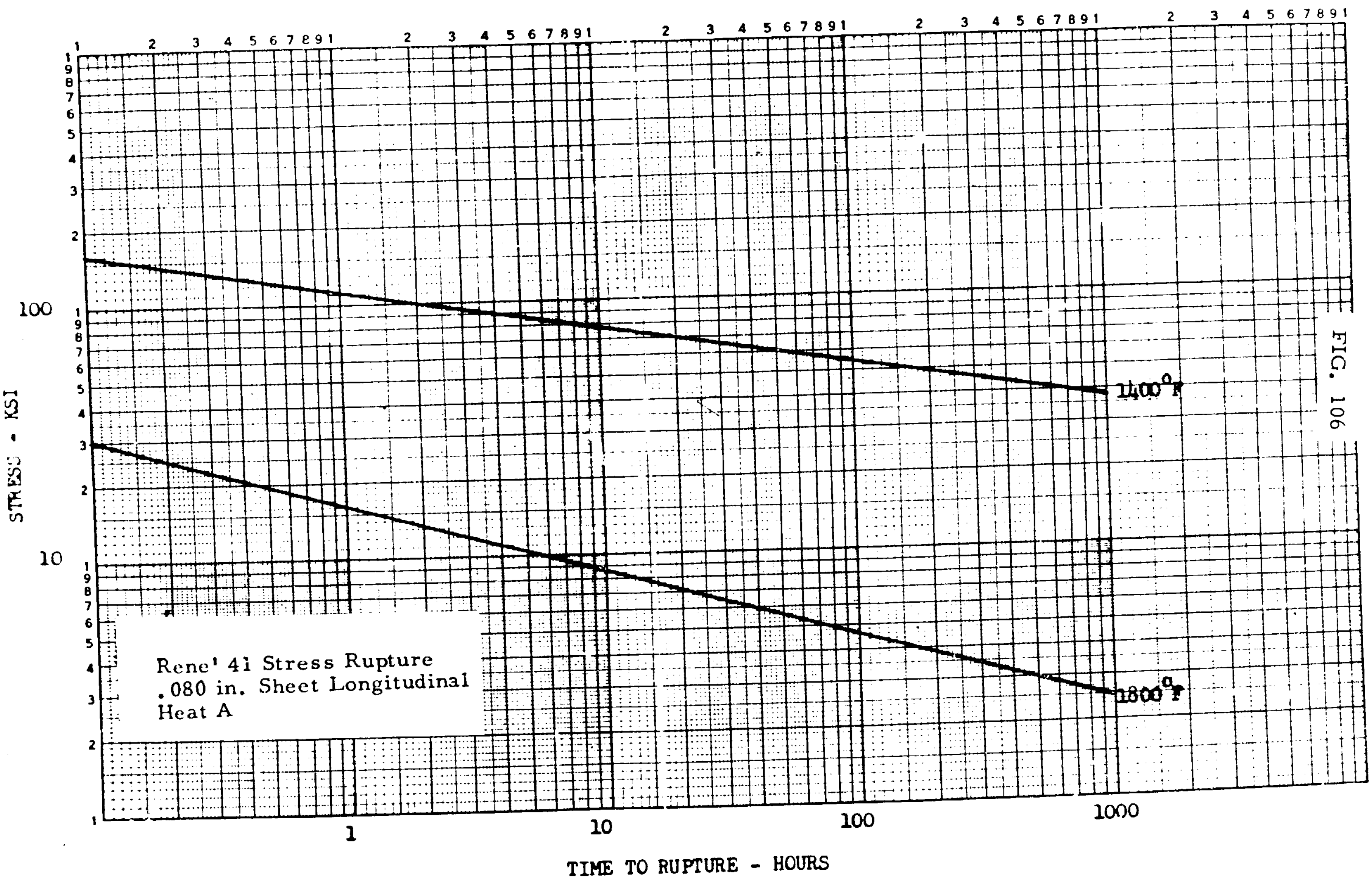

Elevated Temperature
Rene' 41 Stress Rupture
.040 in. Sheet Transverse
Heat A
1200°F
1400°F
1600°F
1800°F
STRESS - KSI
TIME TO RUPTURE - HOURS
1
10
100
1000

FIG. 105

FIG. 106



1400°F
1800°F
Rene' 41 Stress Rupture
.080 in. Sheet Longitudinal
Heat A
STRESS - KSI
100
10
TIME TO RUPTURE - HOURS
1
10
100
1000

FIG. 107

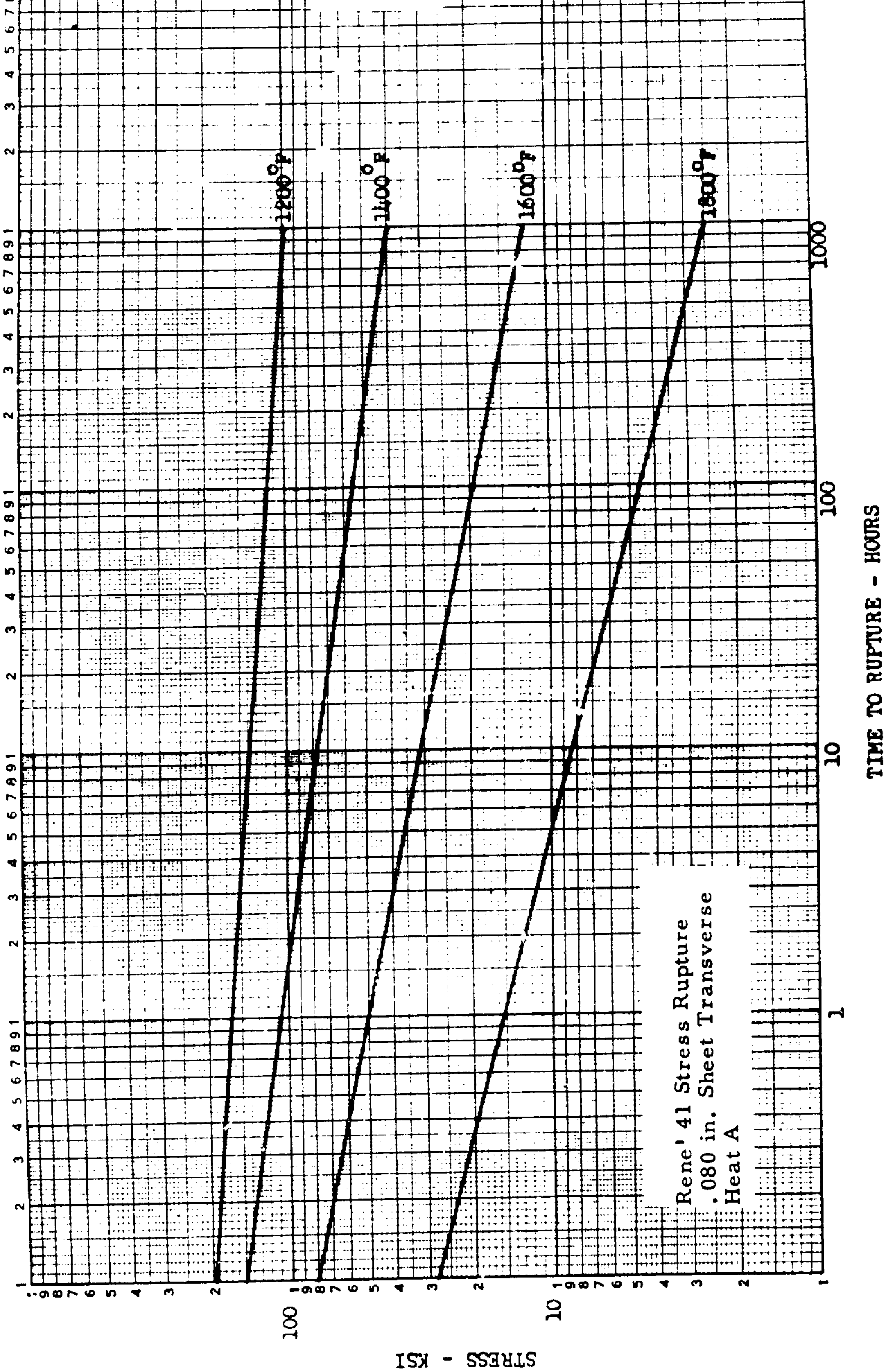

1200°F
1400°F
1600°F
1800°F
TIME TO RUPTURE - HOURS
1
10
100
1000
STRESS - KSI
10
100
Rene' 41 Stress Rupture
.080 in. Sheet Transverse
Heat A

FIG. 108

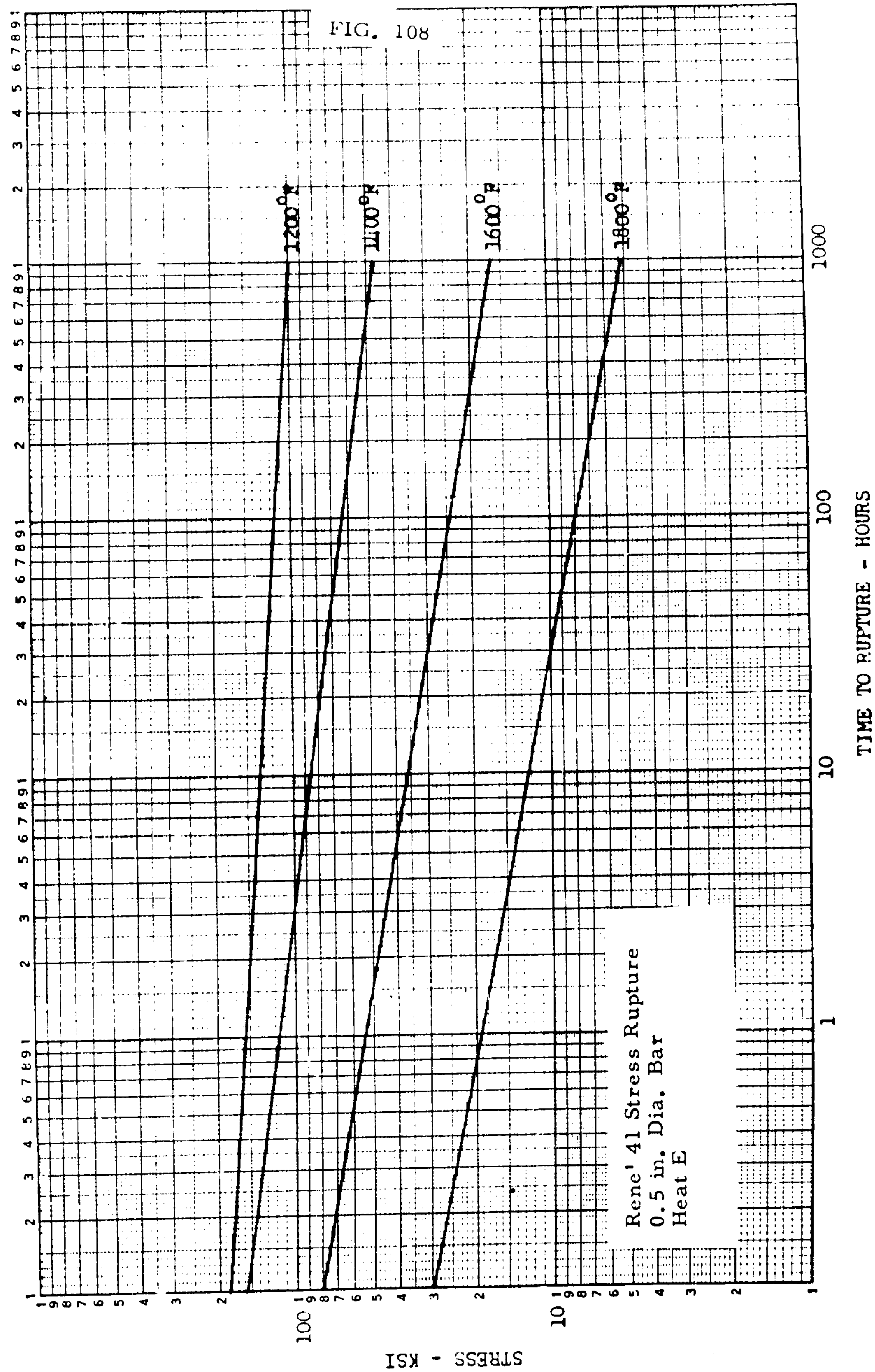
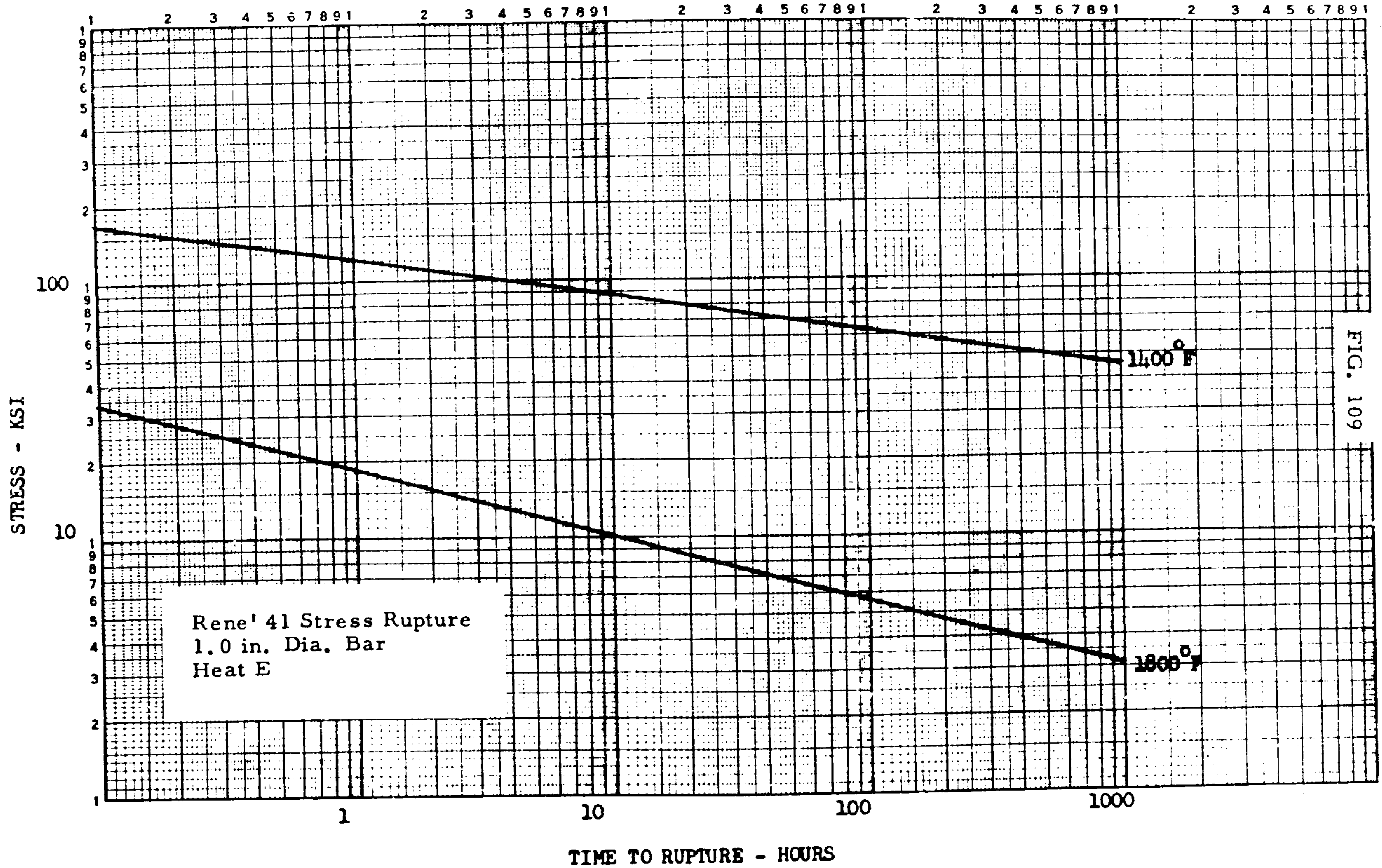
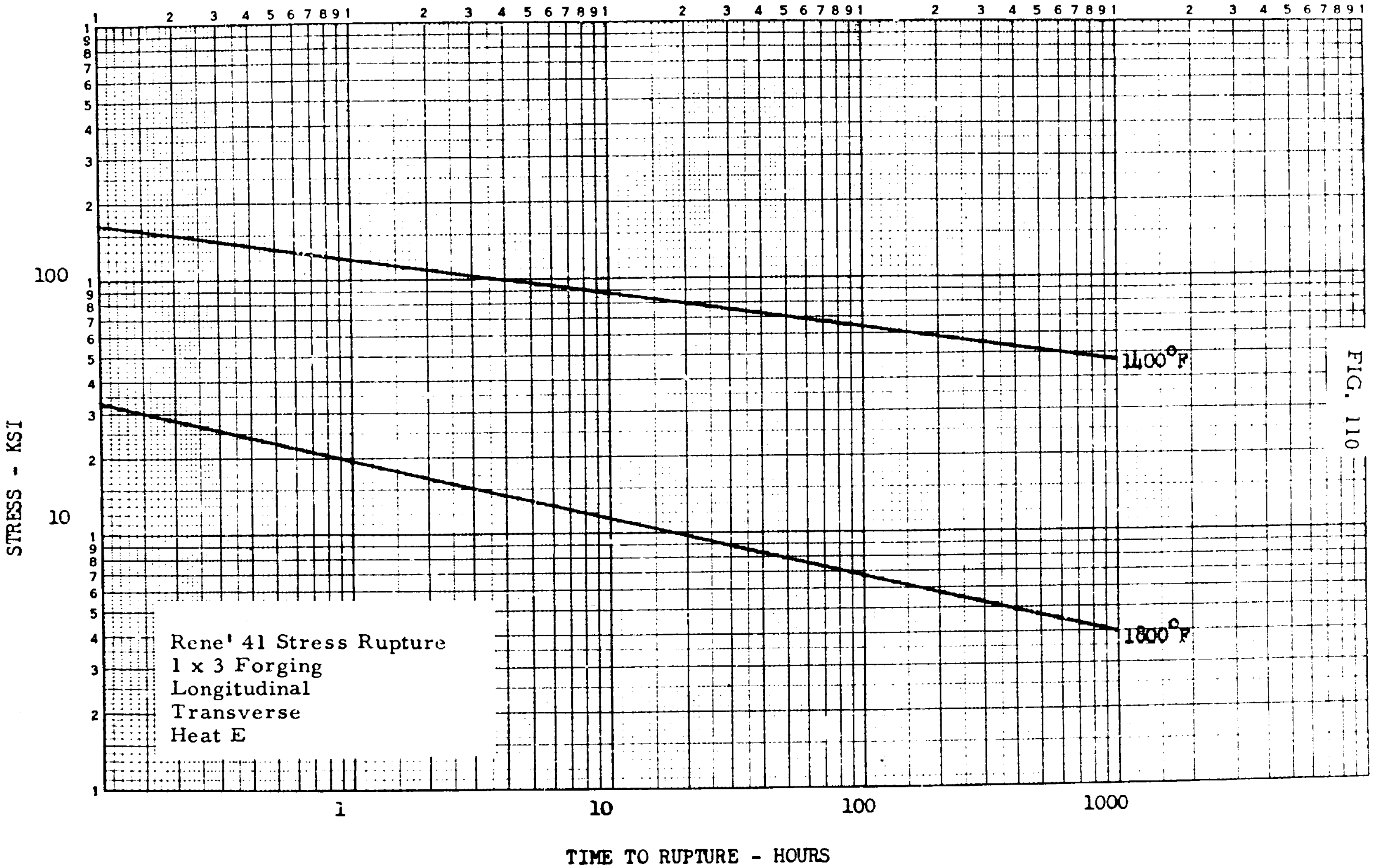

1200°F
1600°F
1800°F
Rene' 41 Stress Rupture
0.5 in. Dia. Bar
Heat E
TIME TO RUPTURE - HOURS
STRESS - KSI

FIG. 109



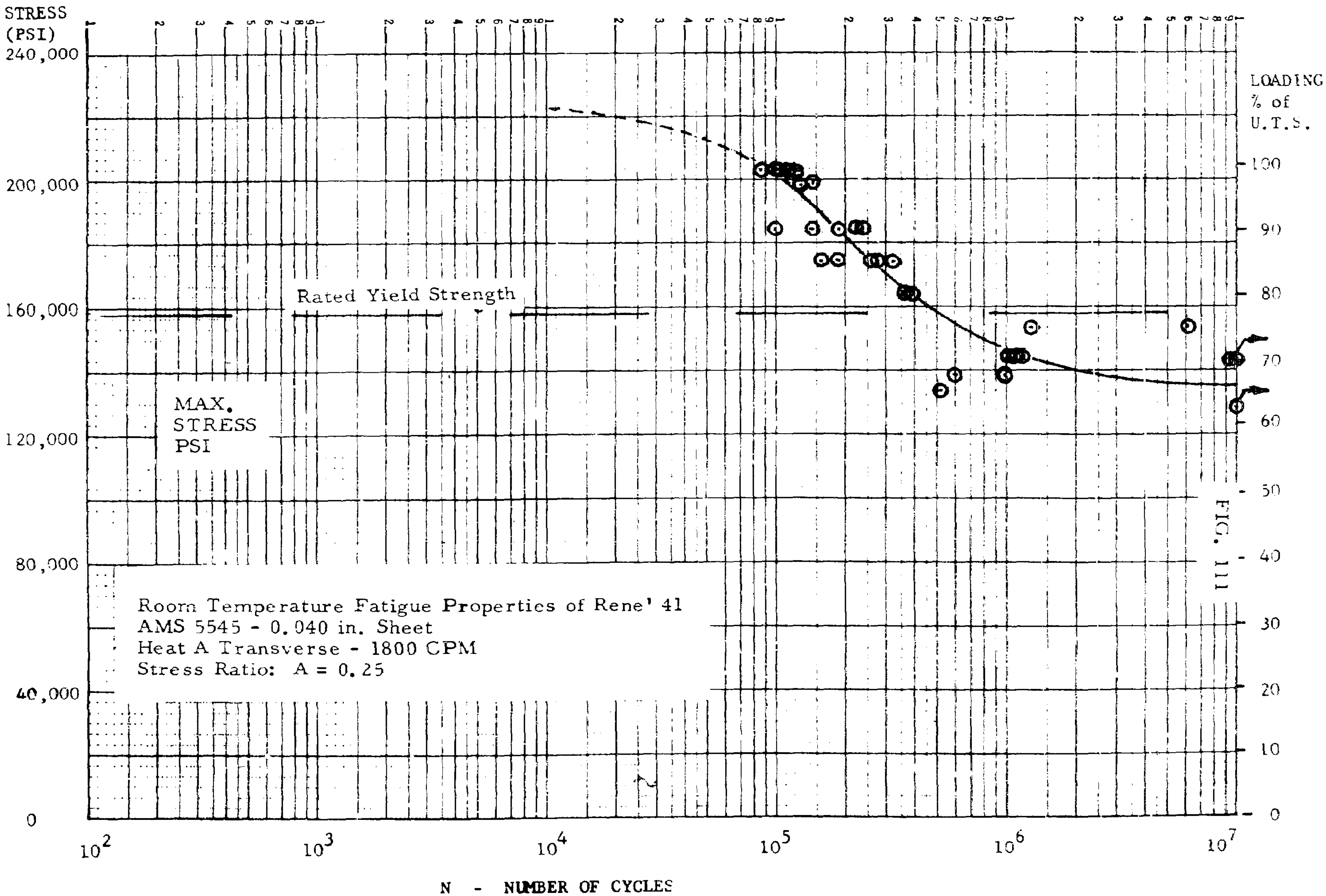
1400°F
1800°F
Rene' 41 Stress Rupture
1.0 in. Dia. Bar
Heat E
STRESS - KSI
100
10
TIME TO RUPTURE - HOURS
1
10
100
1000

FIG. 110


Rene' 41 Stress Rupture
1 x 3 Forging
Longitudinal
Transverse
Heat E
1400°F
1800°F
STRESS - KSI
100
10
1
10
100
1000
TIME TO RUPTURE - HOURS

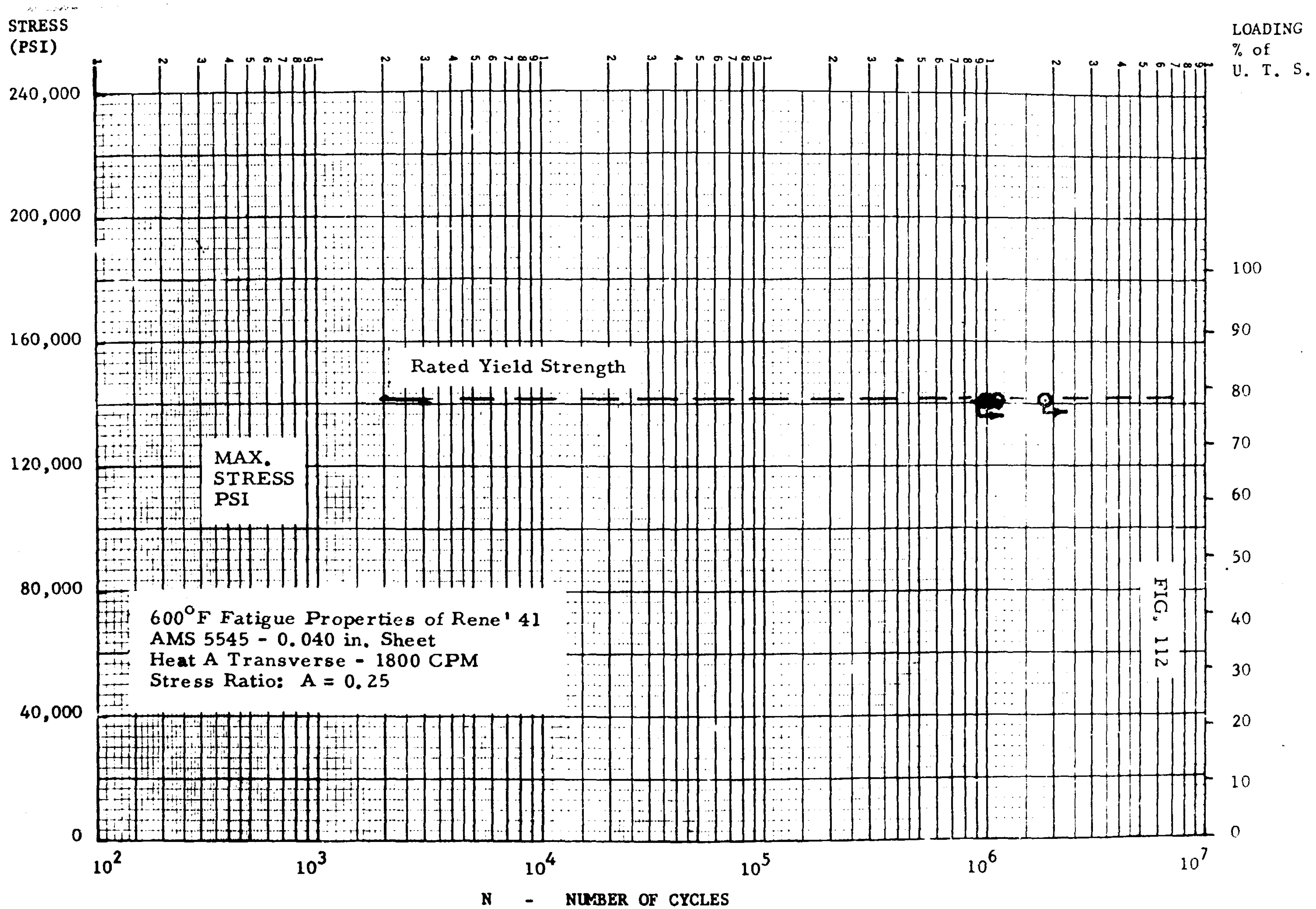
SECTION VII

SECTION 7.1.7 FATIGUE



STRESS (PSI)
240,000
200,000
160,000
120,000
80,000
40,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
Room Temperature Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 111



STRESS (PSI)
240,000
200,000
160,000
120,000
80,000
40,000
0
LOADING % of U. T. S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
600°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
FIG. 112
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

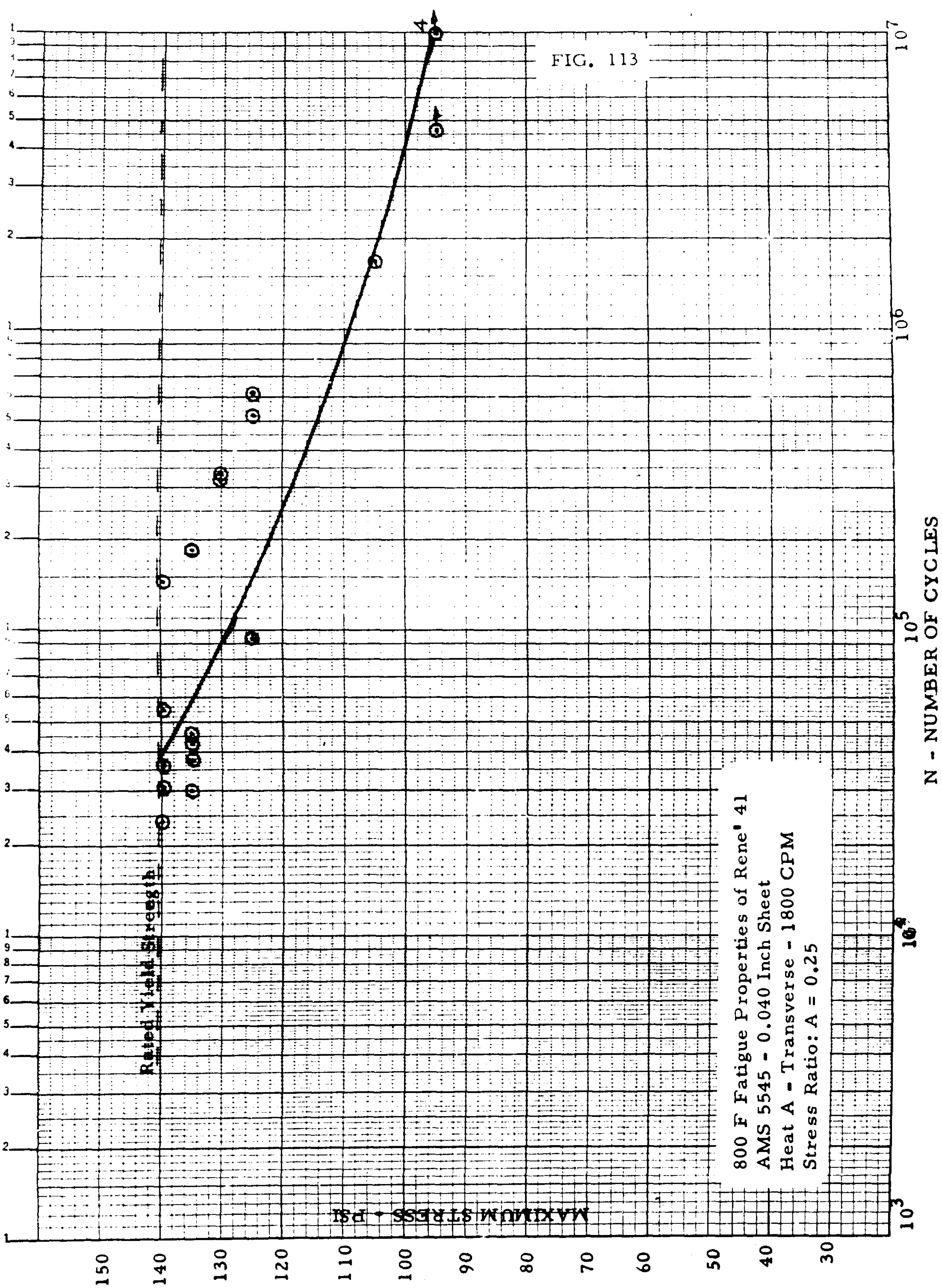
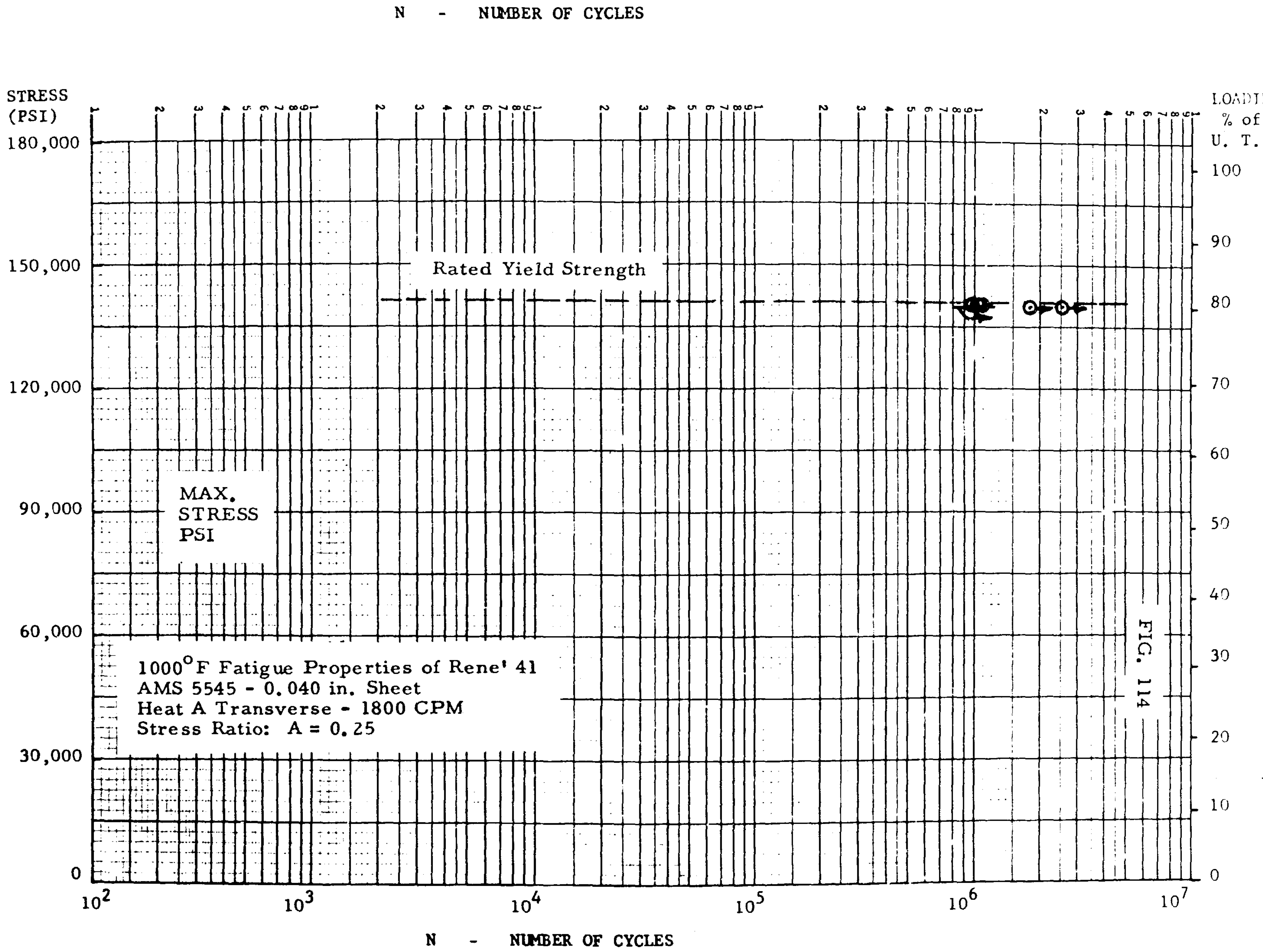


FIG. 113
800 F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 Inch Sheet
Heat A - Transverse - 1800 CPM
Stress Ratio: A = 0.25
Rated Yield Strength
N - NUMBER OF CYCLES
MAXIMUM STRESS - PSI
150
140
130
120
110
100
90
80
70
60
50
40
30
10^3
10^4
10^5
10^6
10^7


N - NUMBER OF CYCLES
STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U. T.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1000°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
FIG. 114
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

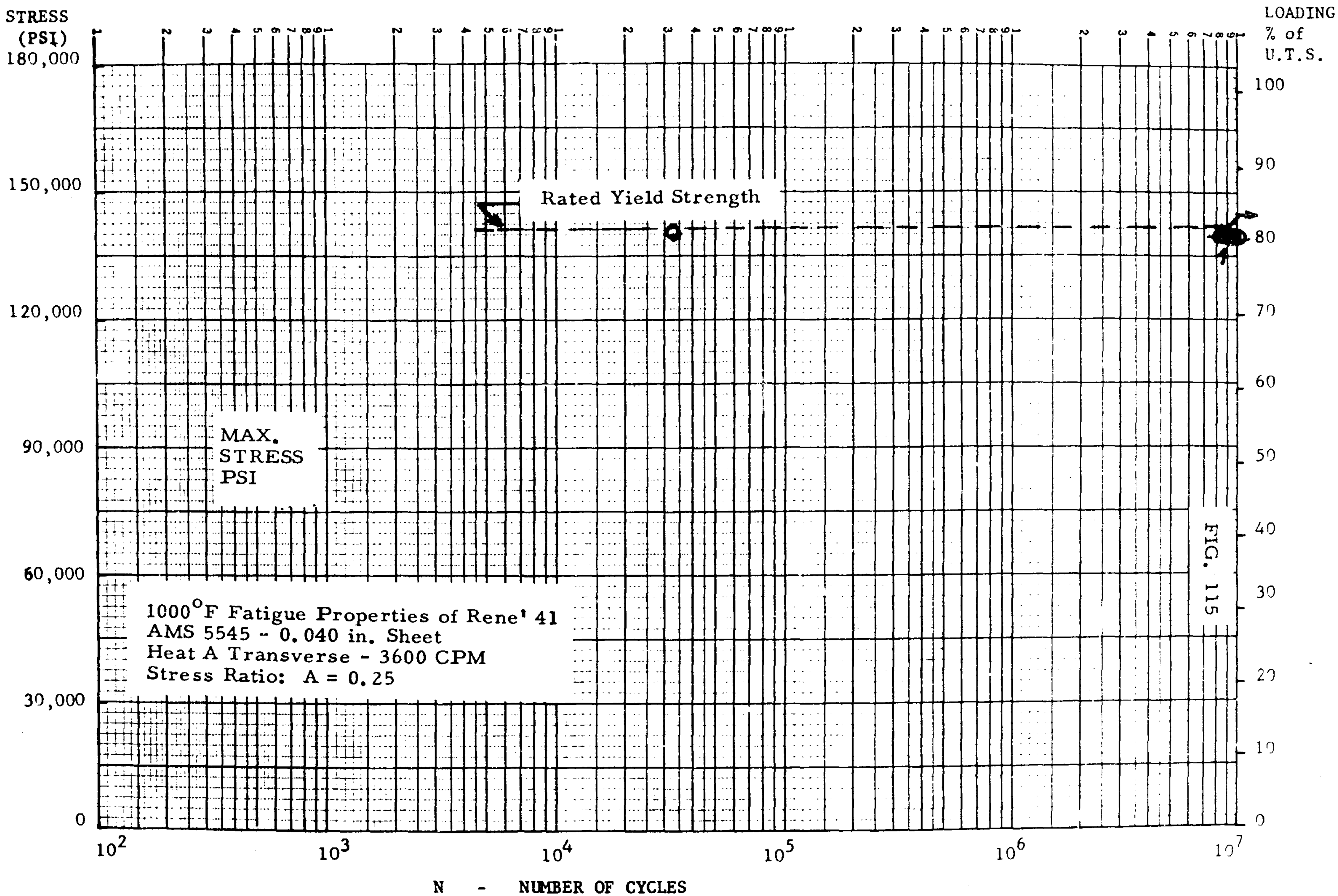


FIG. 115

1000°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 3600 CPM
Stress Ratio: A = 0.25

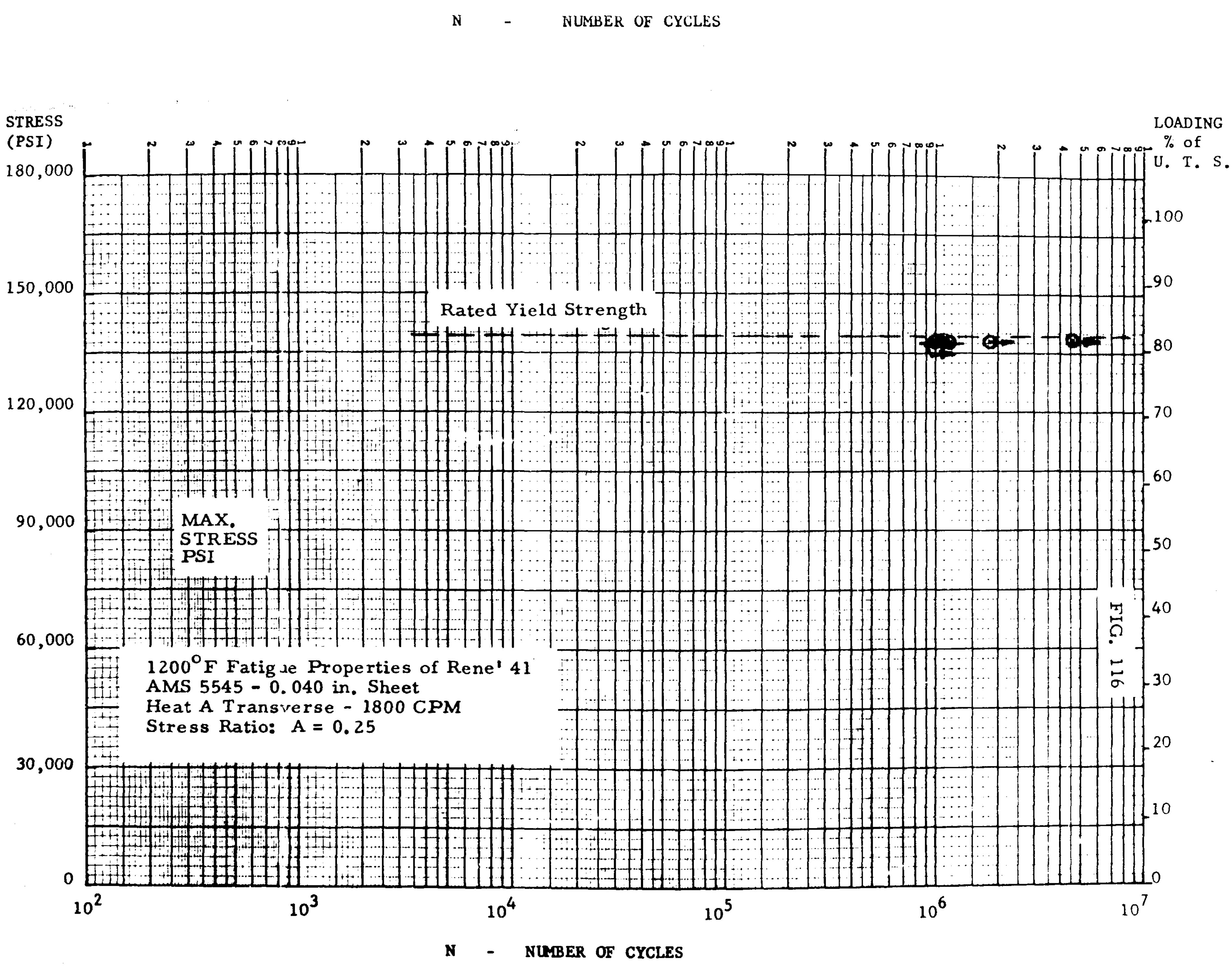
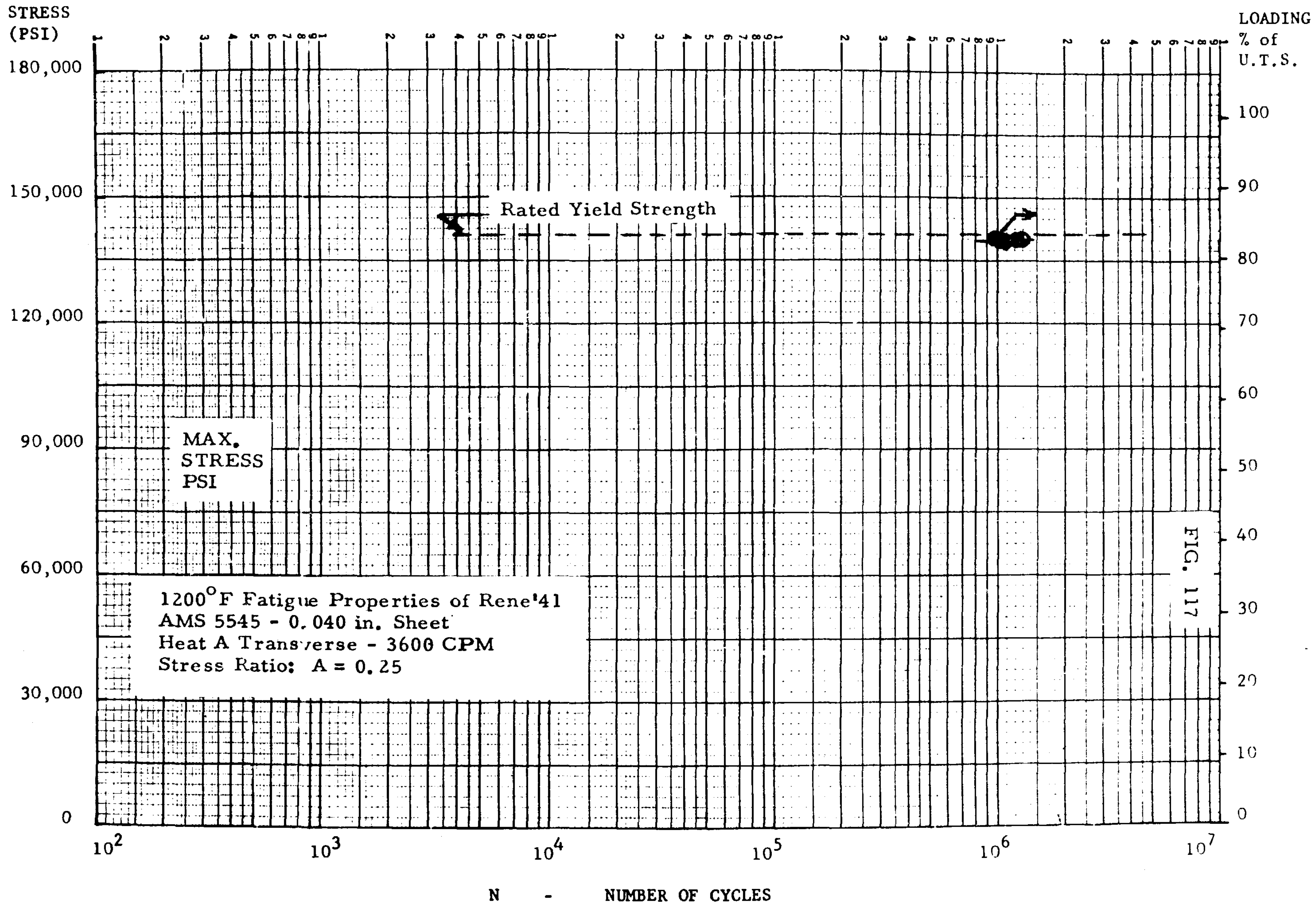

N - NUMBER OF CYCLES
STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U. T. S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1200°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 116



STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1200°F Fatigue Properties of Rene'41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 3600 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 117

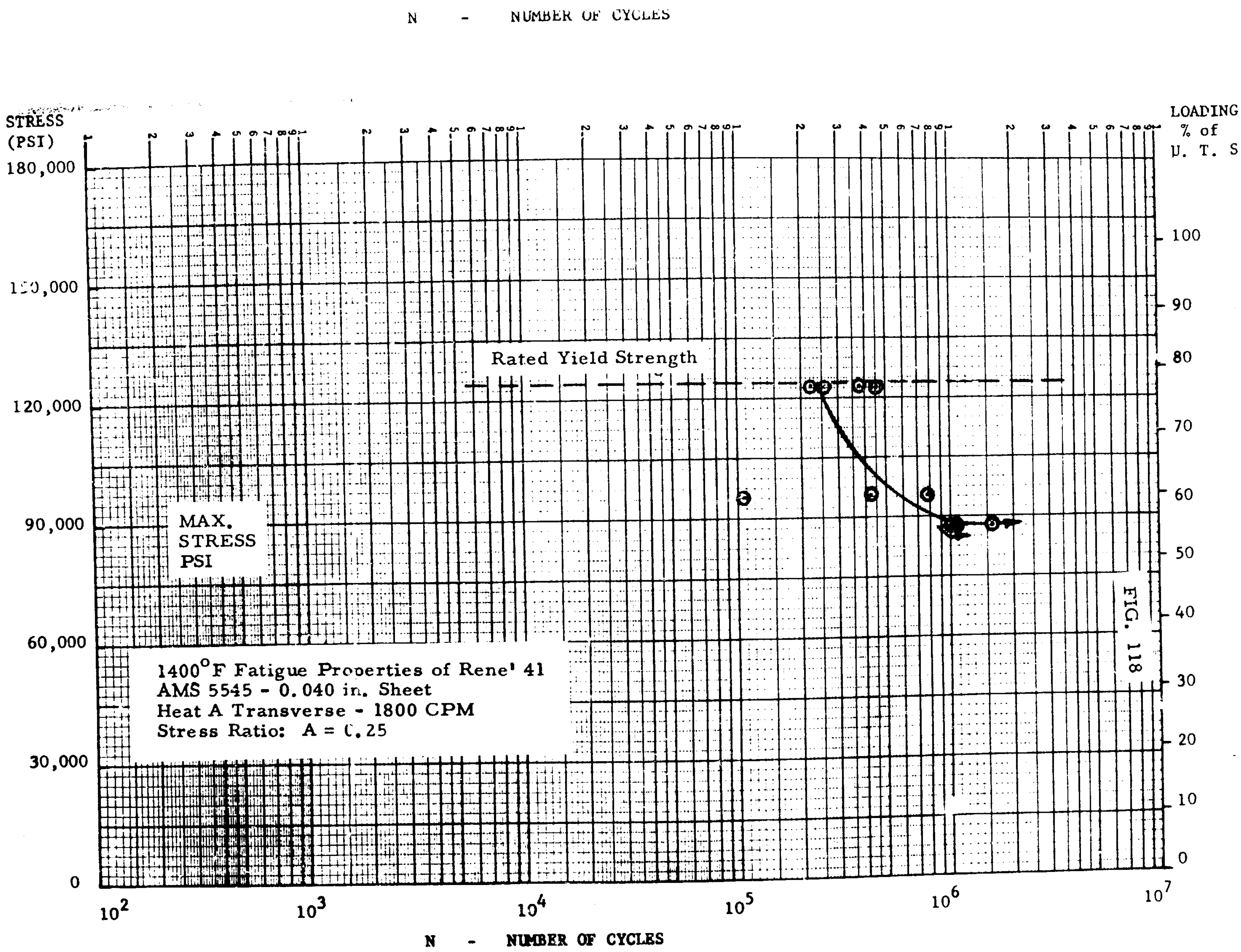

N - NUMBER OF CYCLES
STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U. T. S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1400°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 118

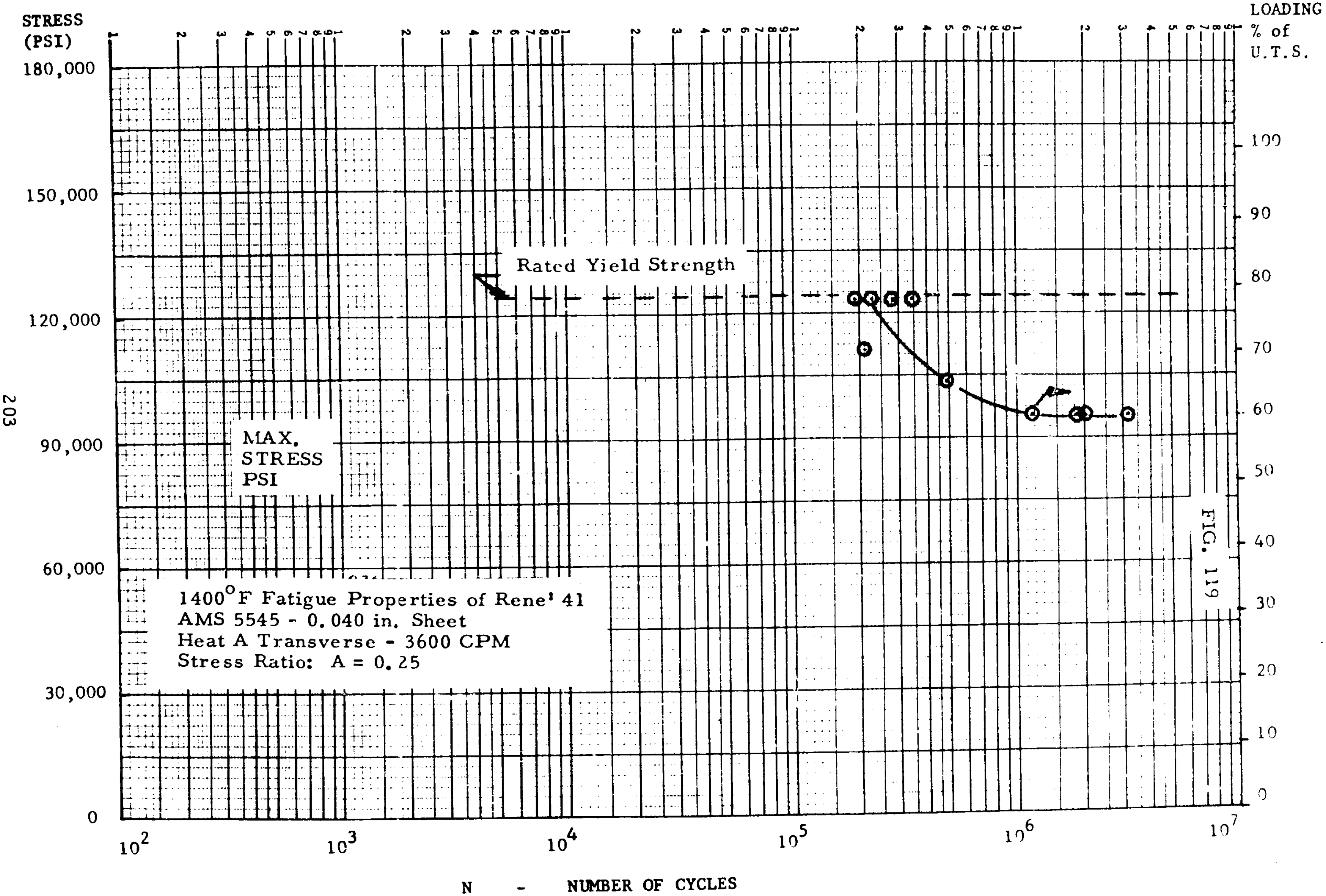
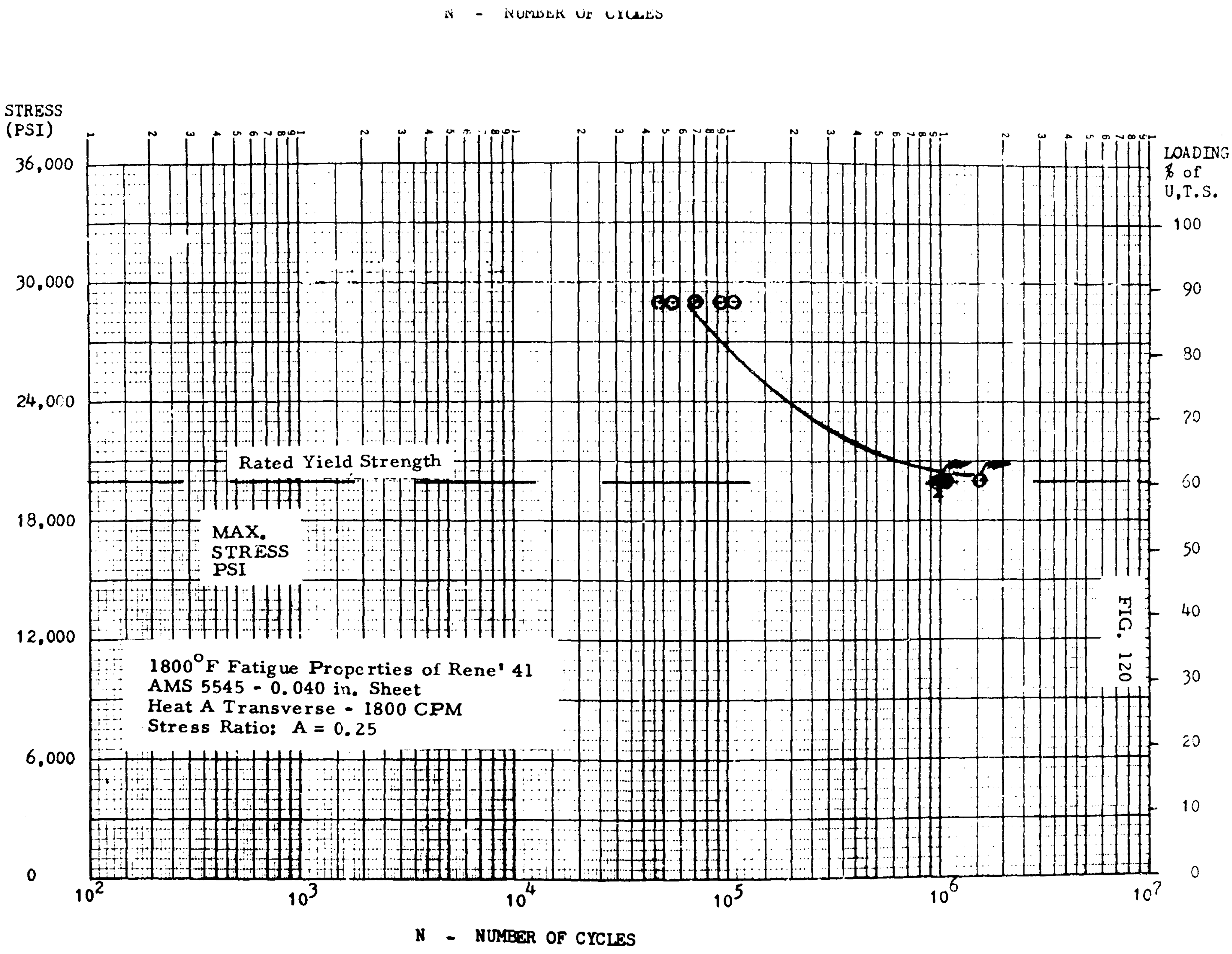

STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1400°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 3600 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 119


N - NUMBER OF CYCLES
STRESS (PSI)
36,000
30,000
24,000
18,000
12,000
6,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1800°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES
FIG. 120

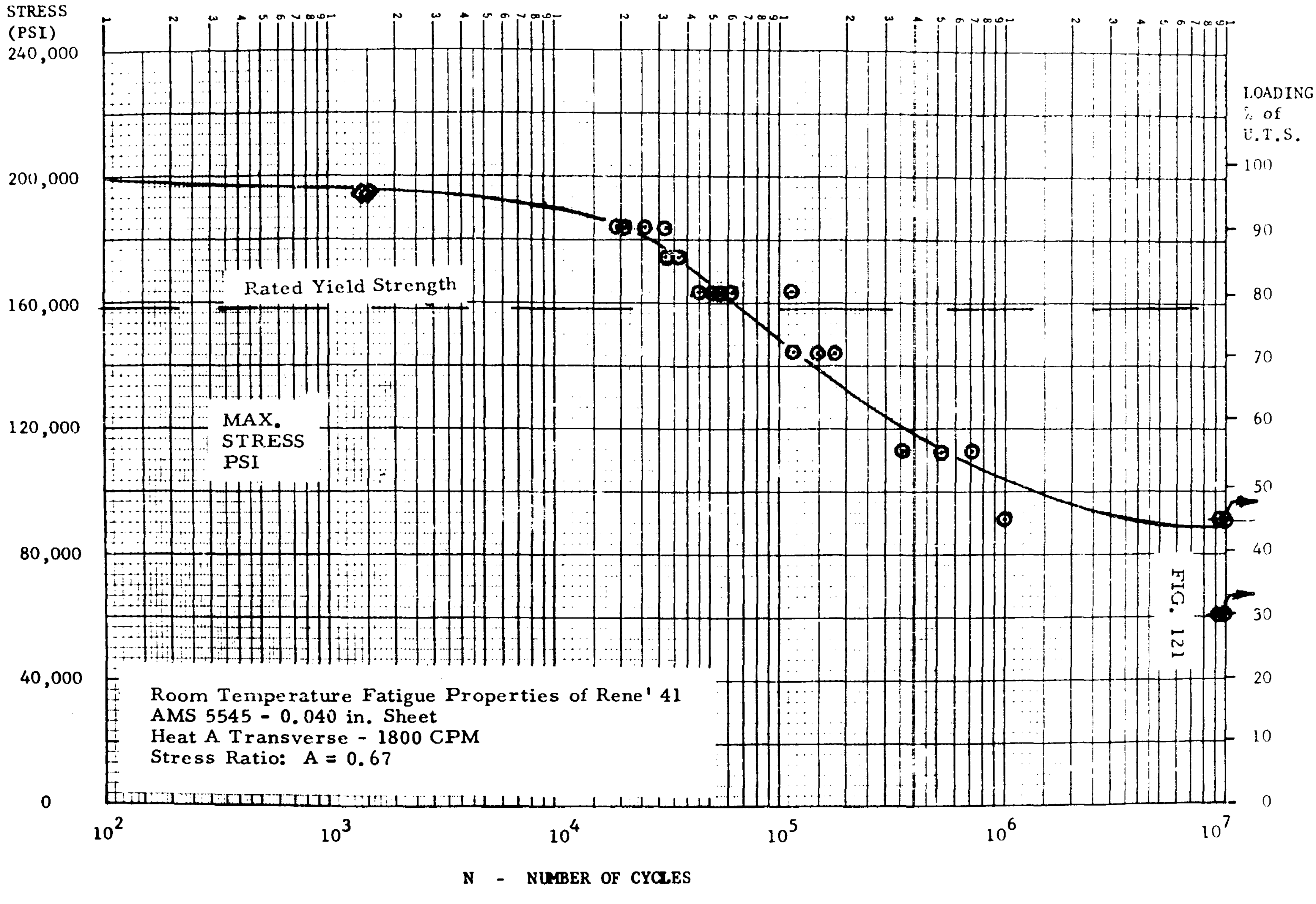

STRESS
(PSI)
240,000
200,000
160,000
120,000
80,000
40,000
0
LOADING
% of
U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX.
STRESS
PSI
Room Temperature Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 121

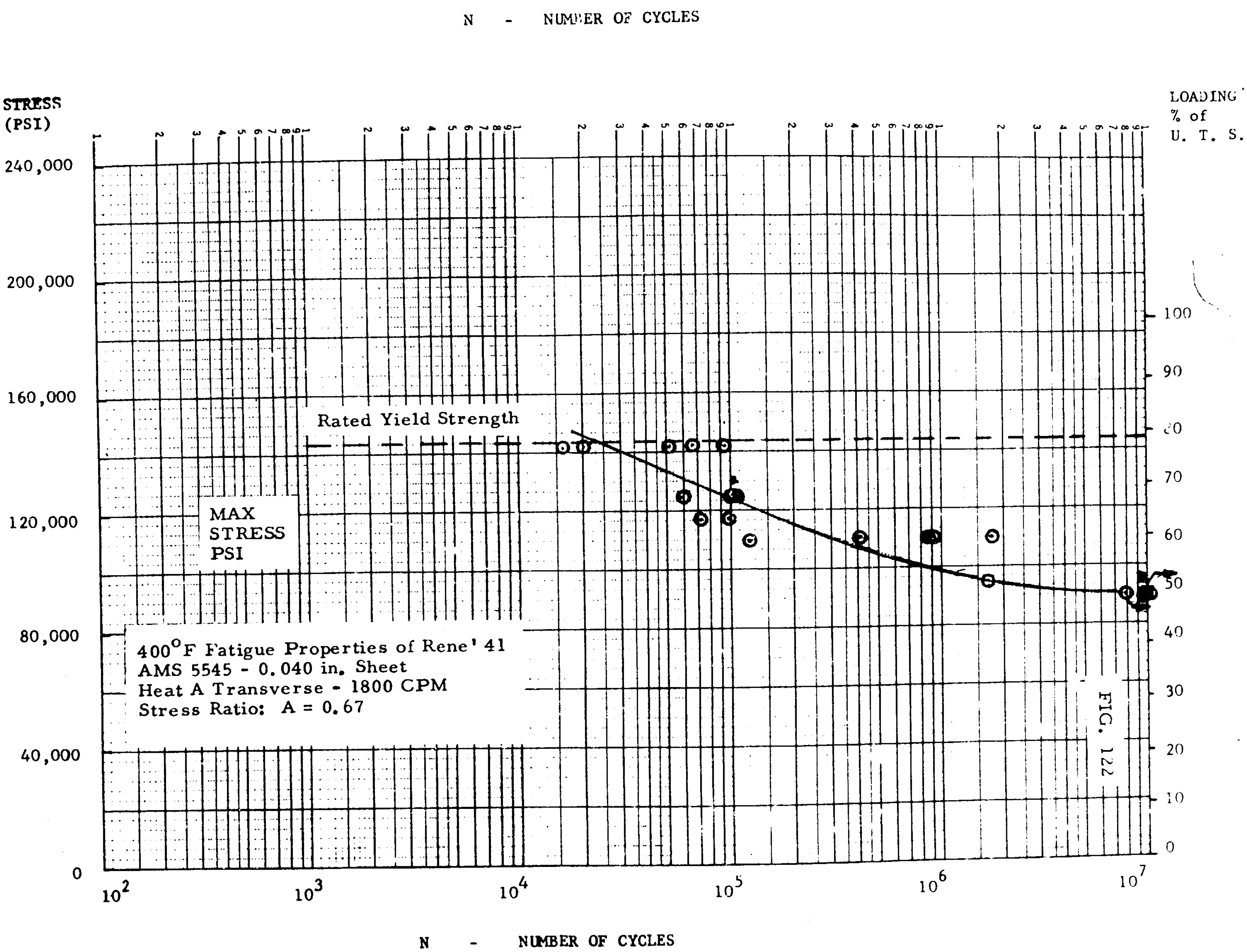

N - NUMBER OF CYCLES
STRESS (PSI)
240,000
200,000
160,000
120,000
80,000
40,000
0
LOADING % of U. T. S.
100
90
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX STRESS PSI
400°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 122

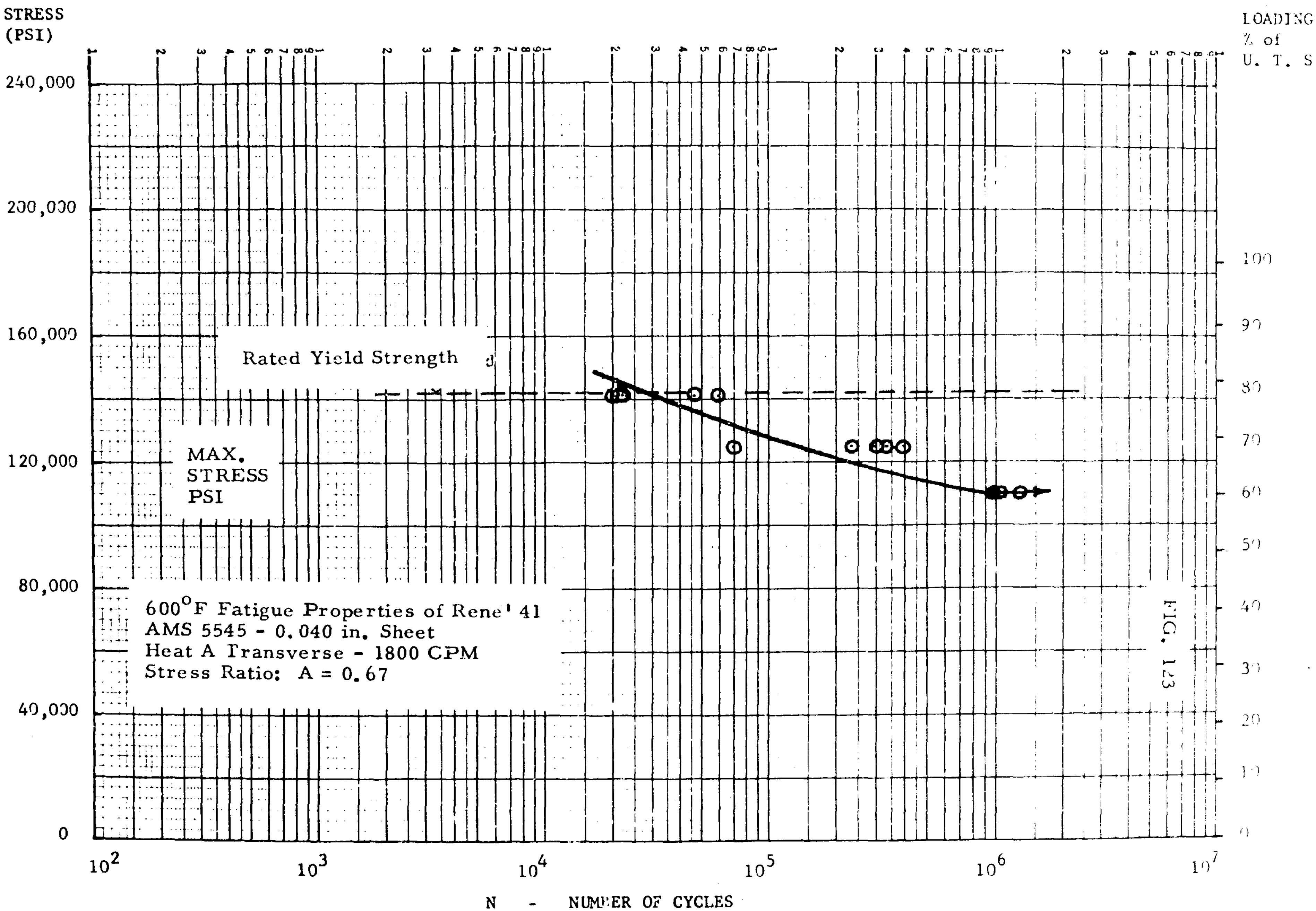

STRESS (PSI)
LOADING % of U. T. S
Rated Yield Strength
MAX. STRESS PSI
600°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
N - NUMBER OF CYCLES

FIG. 123

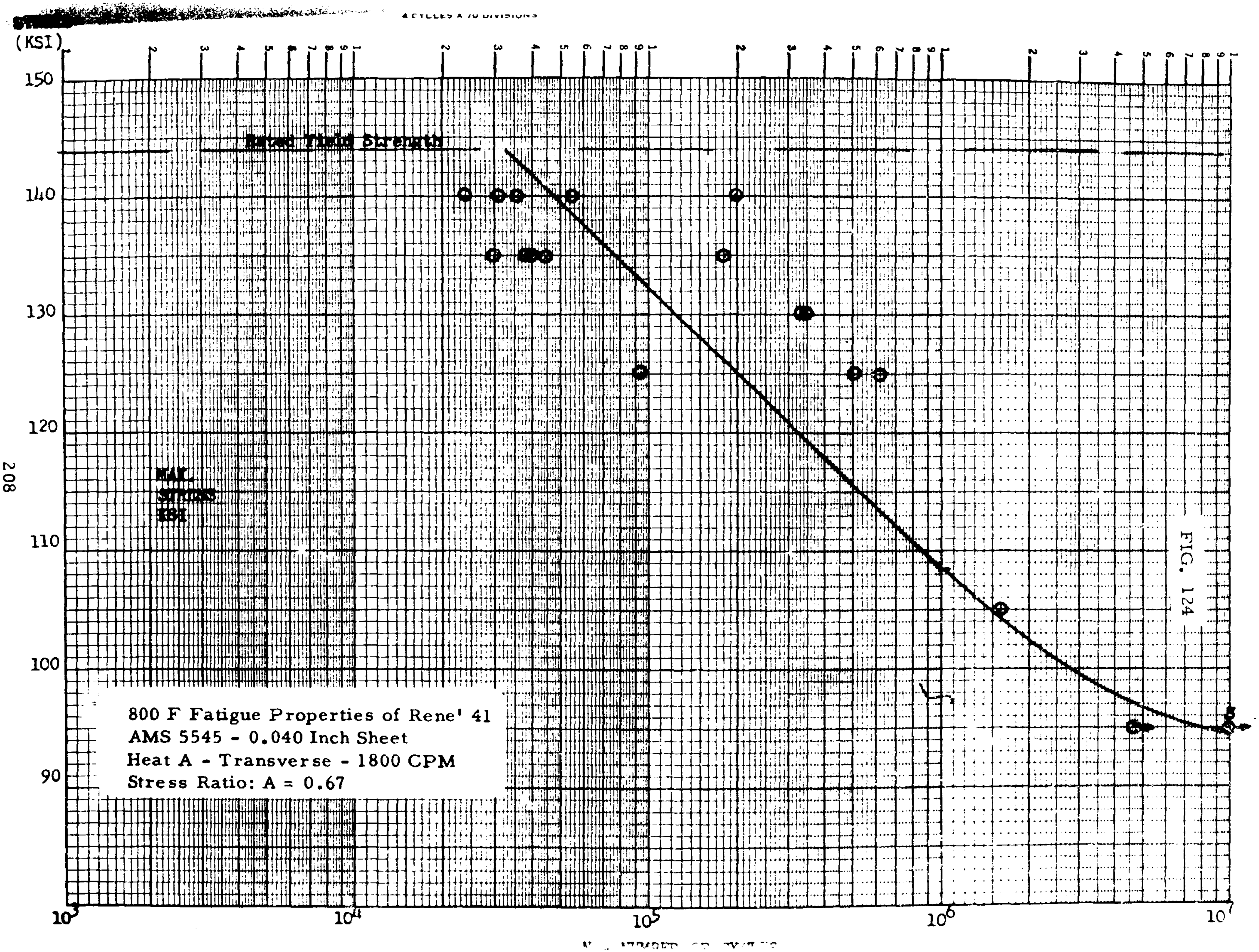


FIG. 124
STRESS (KSI)
Rated Yield Strength
MAX. STRESS KSI
800 F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 Inch Sheet
Heat A - Transverse - 1800 CPM
Stress Ratio: A = 0.67

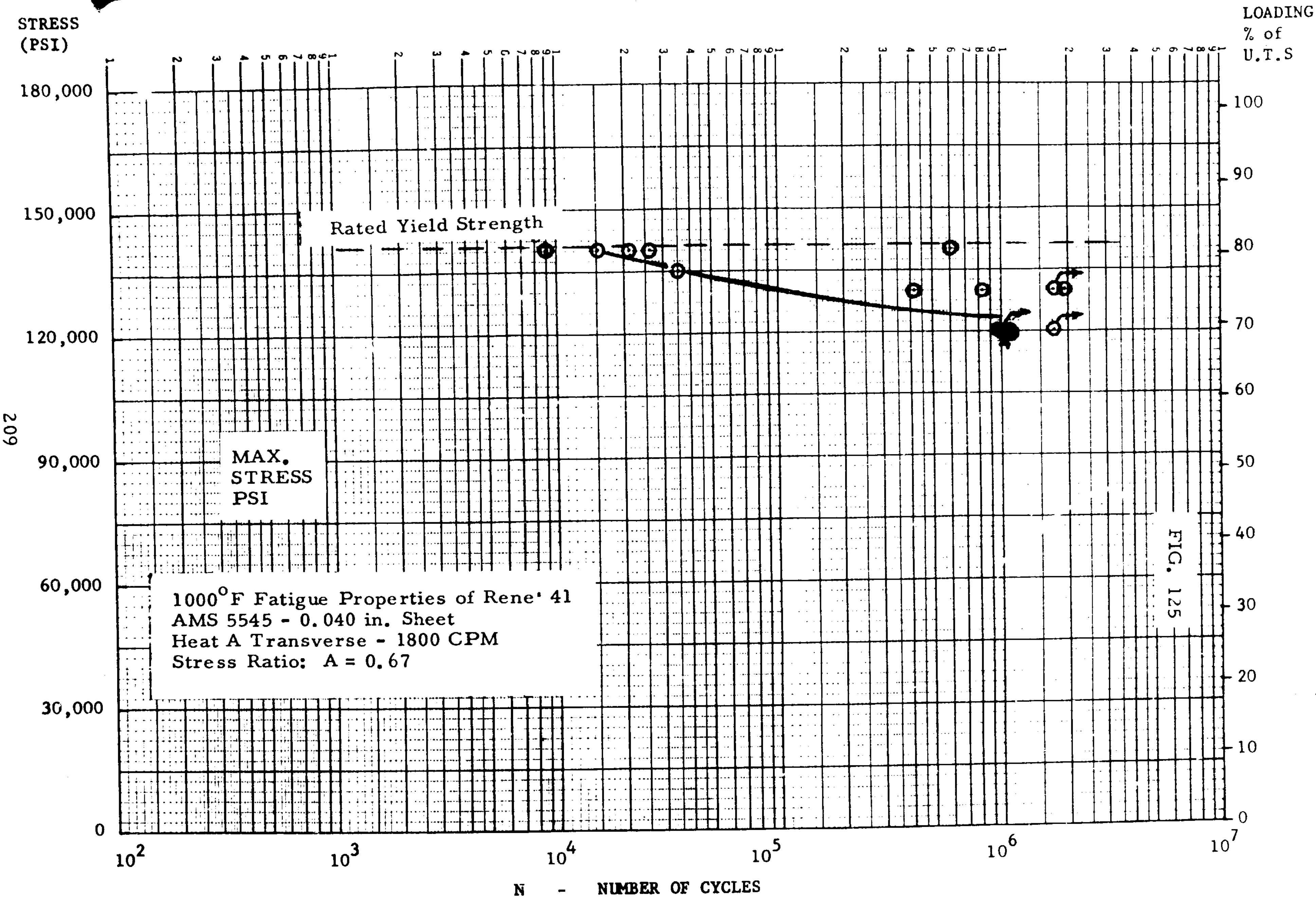

STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U.T.S
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1000°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 125

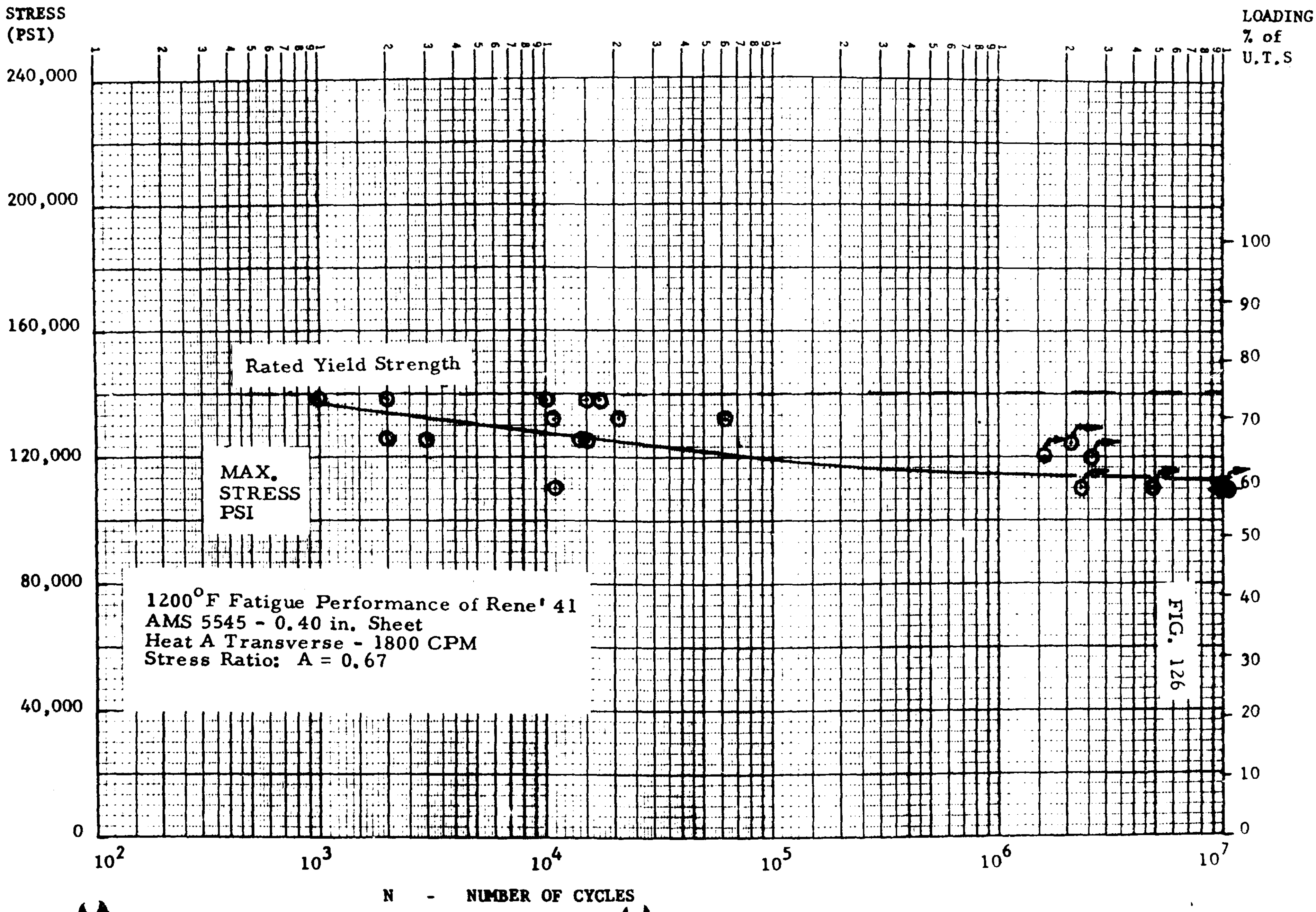

STRESS (PSI)
240,000
200,000
160,000
120,000
80,000
40,000
0
LOADING % of U.T.S
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1200°F Fatigue Performance of Rene' 41
AMS 5545 - 0.40 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 126

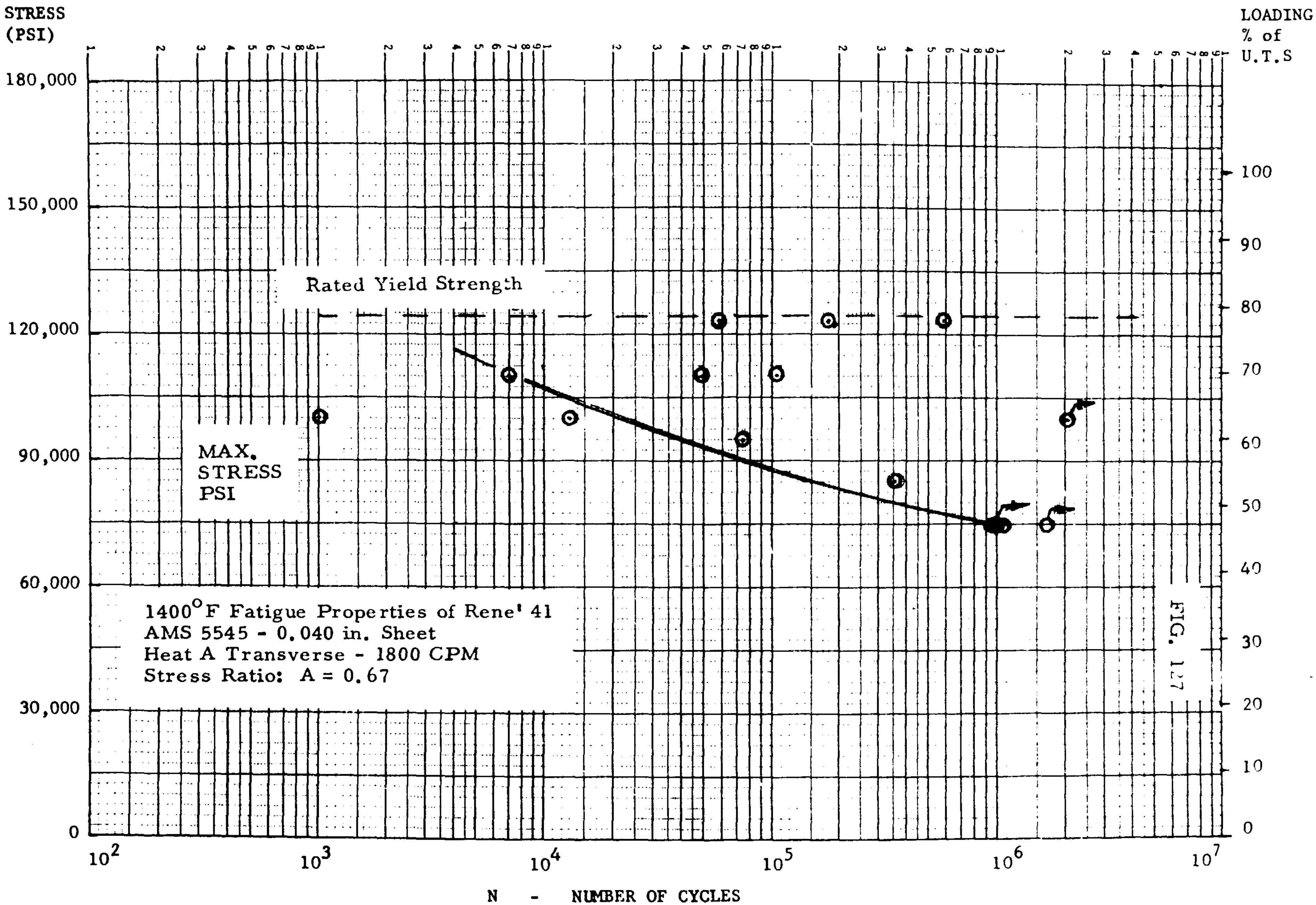
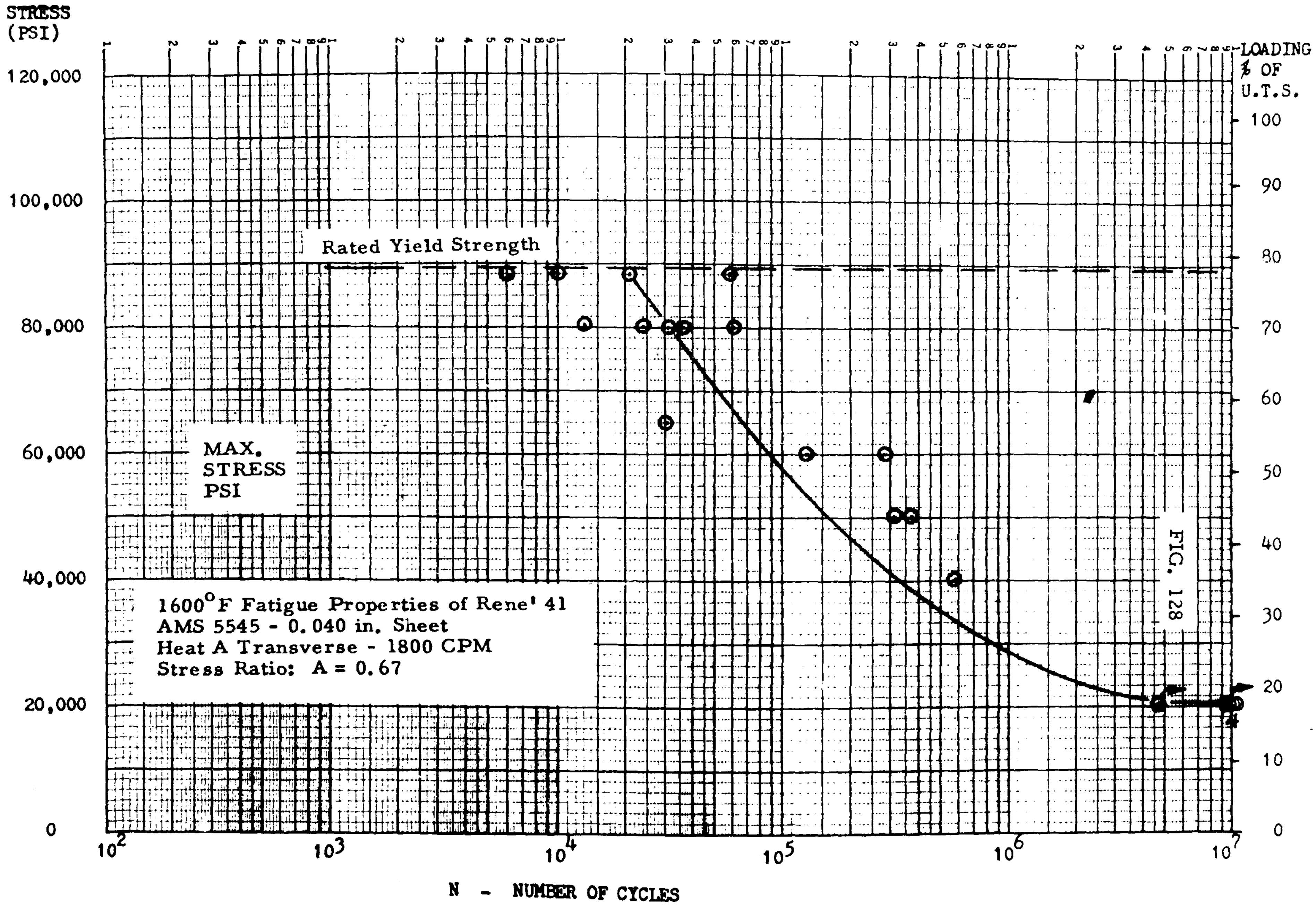

STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U.T.S
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1400°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 127



STRESS (PSI)
LOADING % OF U.T.S.
Rated Yield Strength
MAX. STRESS PSI
1600°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
N - NUMBER OF CYCLES

FIG. 128

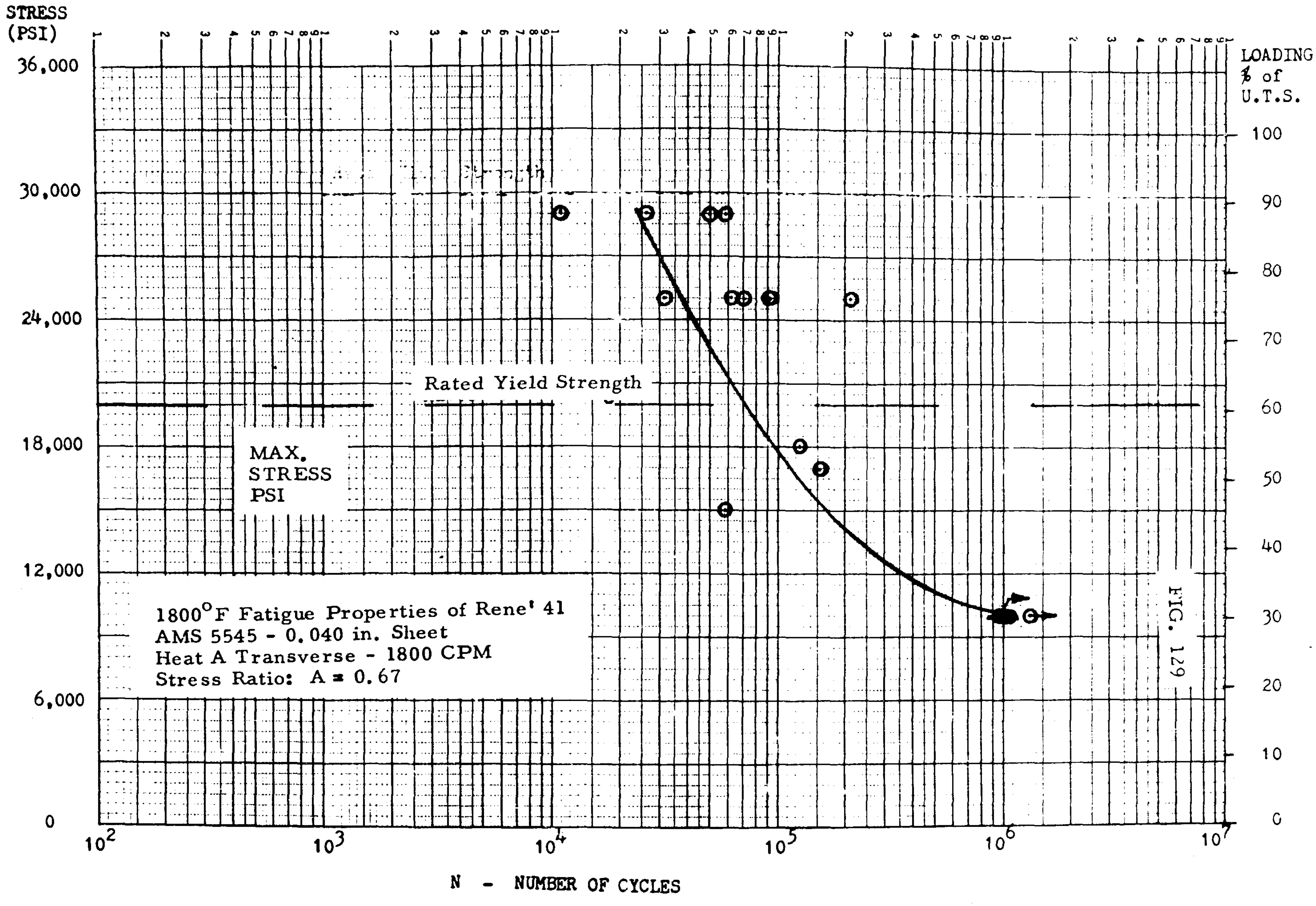
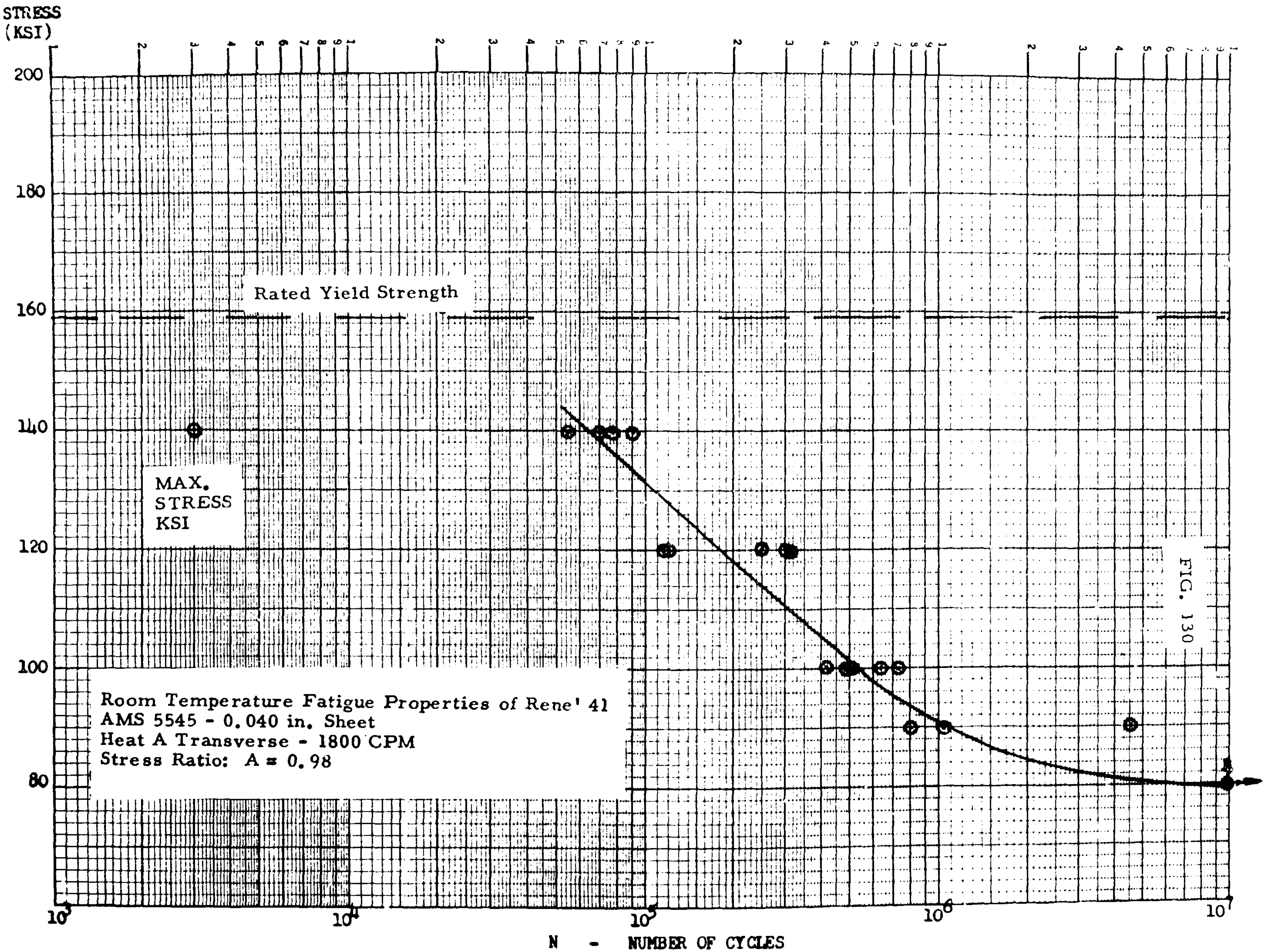

STRESS (PSI)
36,000
30,000
24,000
18,000
12,000
6,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1800°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 129

FIG. 130


STRESS (KSI)
200
180
160
140
120
100
80
Rated Yield Strength
MAX. STRESS KSI
Room Temperature Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

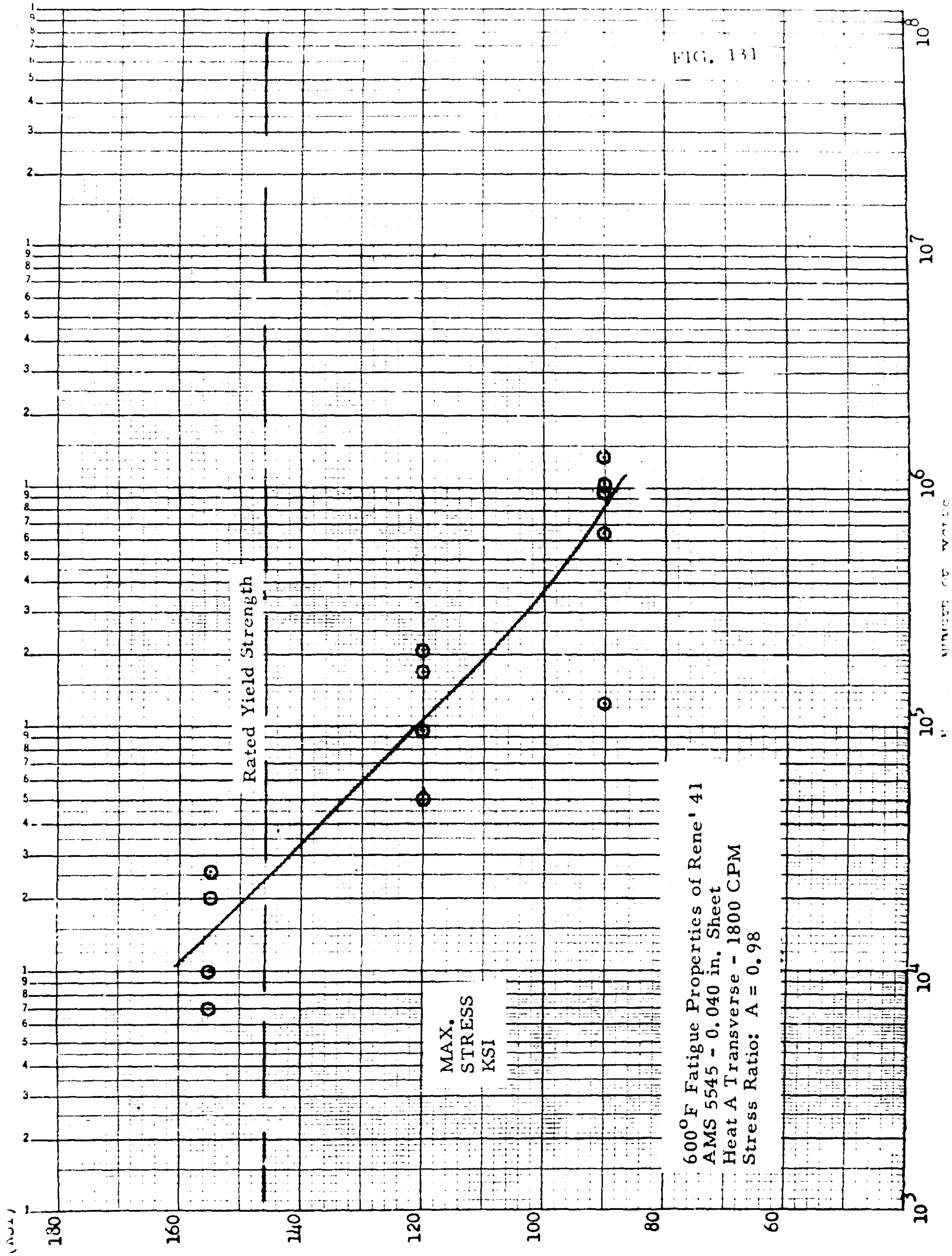

Rated Yield Strength
MAX.
STRESS
KSI
600°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
180
160
140
120
100
80
60
10^3
10^4
10^5
10^6
10^7
10^8

FIG. 131

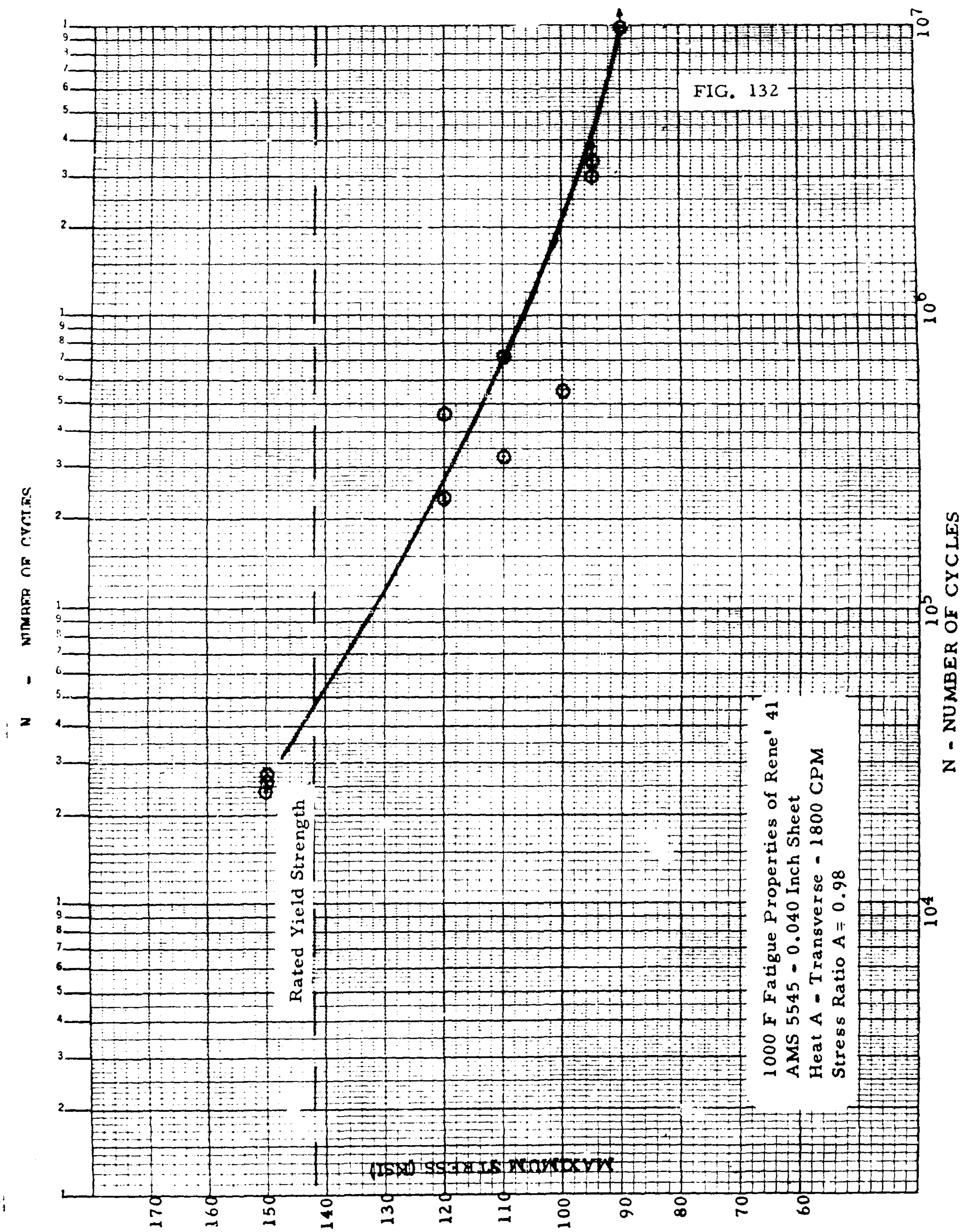


FIG. 132
1000 F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 Inch Sheet
Heat A - Transverse - 1800 CPM
Stress Ratio A = 0.98
Rated Yield Strength
MAXIMUM STRESS (KSI)
N - NUMBER OF CYCLES
10^4
10^5
10^6
10^7
170
160
150
140
130
120
110
100
90
80
70
60

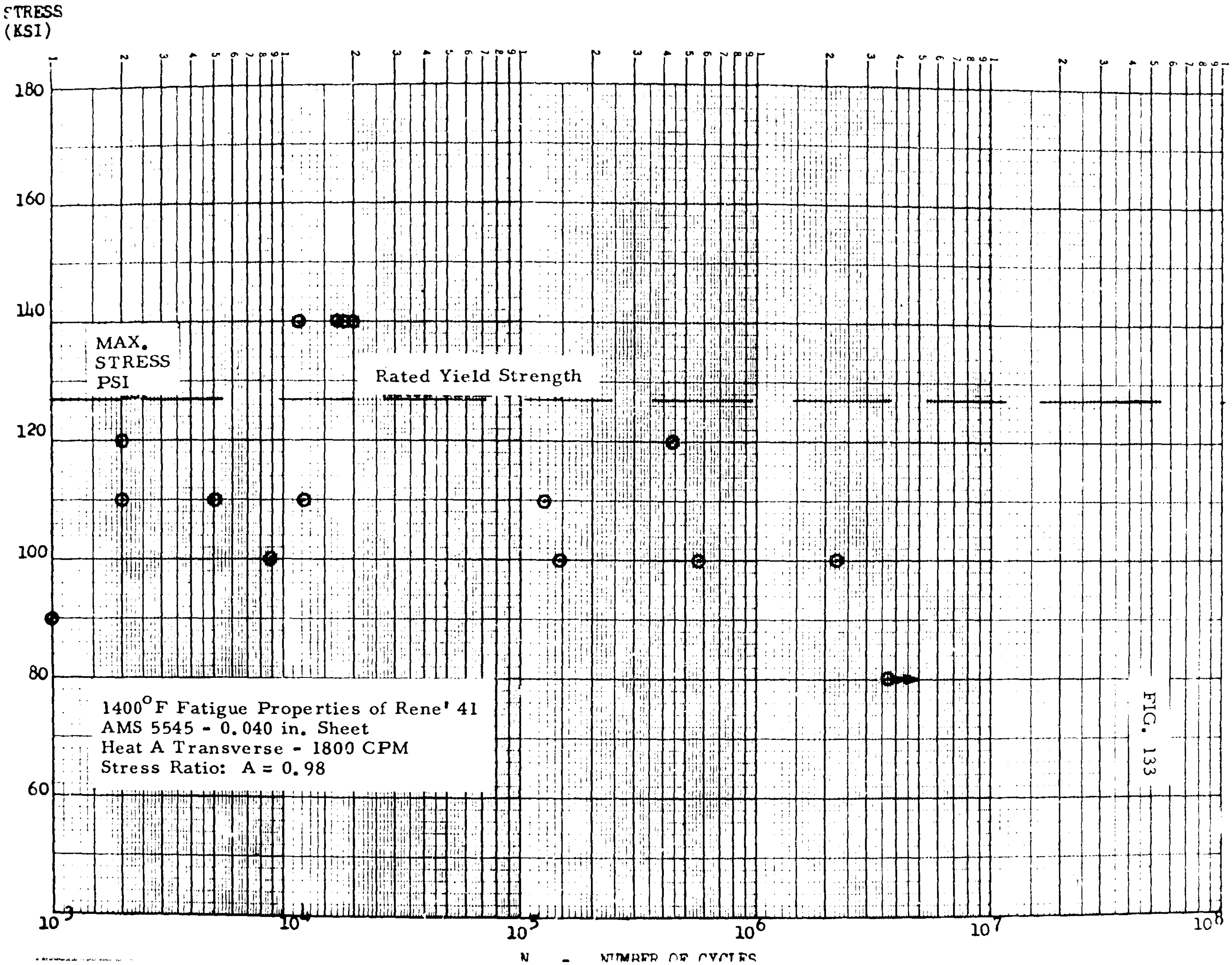
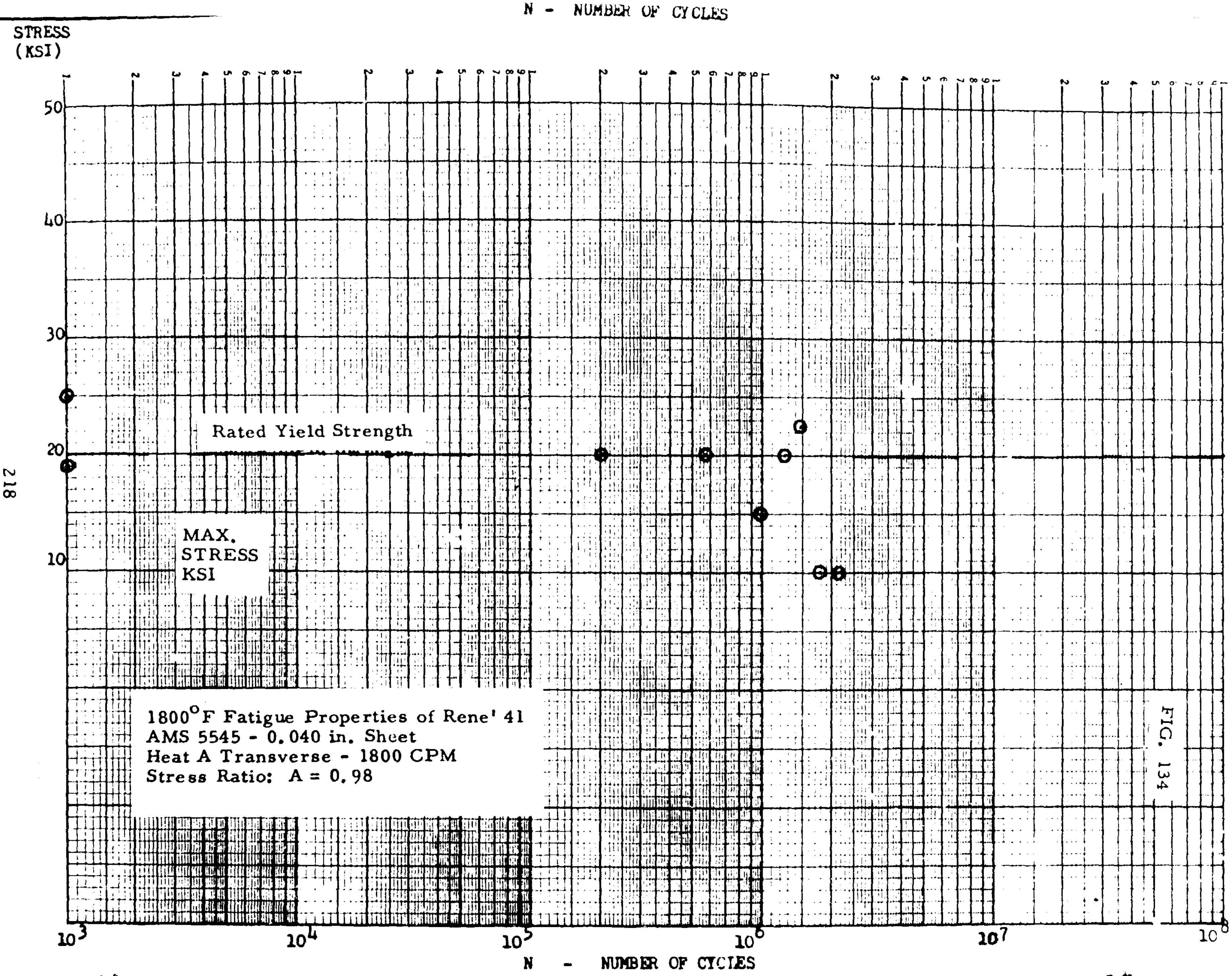

STRESS (KSI)
180
160
140
120
100
80
60
MAX. STRESS PSI
Rated Yield Strength
1400°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
10^3
10^4
10^5
10^6
10^7
10^8
N - NUMBER OF CYCLES

FIG. 133



N - NUMBER OF CYCLES
STRESS (KSI)
50
40
30
20
10
Rated Yield Strength
MAX. STRESS KSI
1800°F Fatigue Properties of Rene' 41
AMS 5545 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
FIG. 134
10^3
10^4
10^5
10^6
10^7
10^8
N - NUMBER OF CYCLES

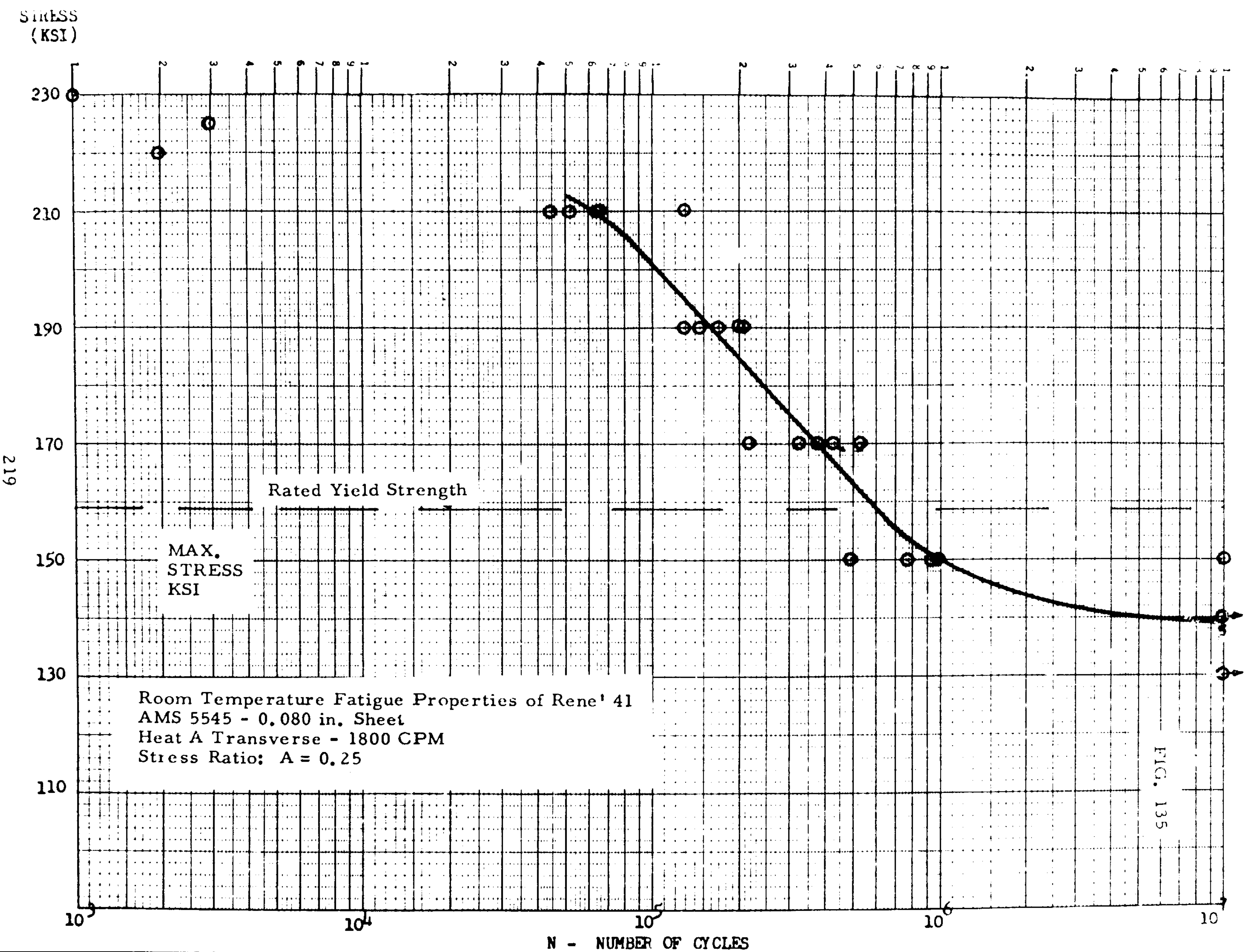
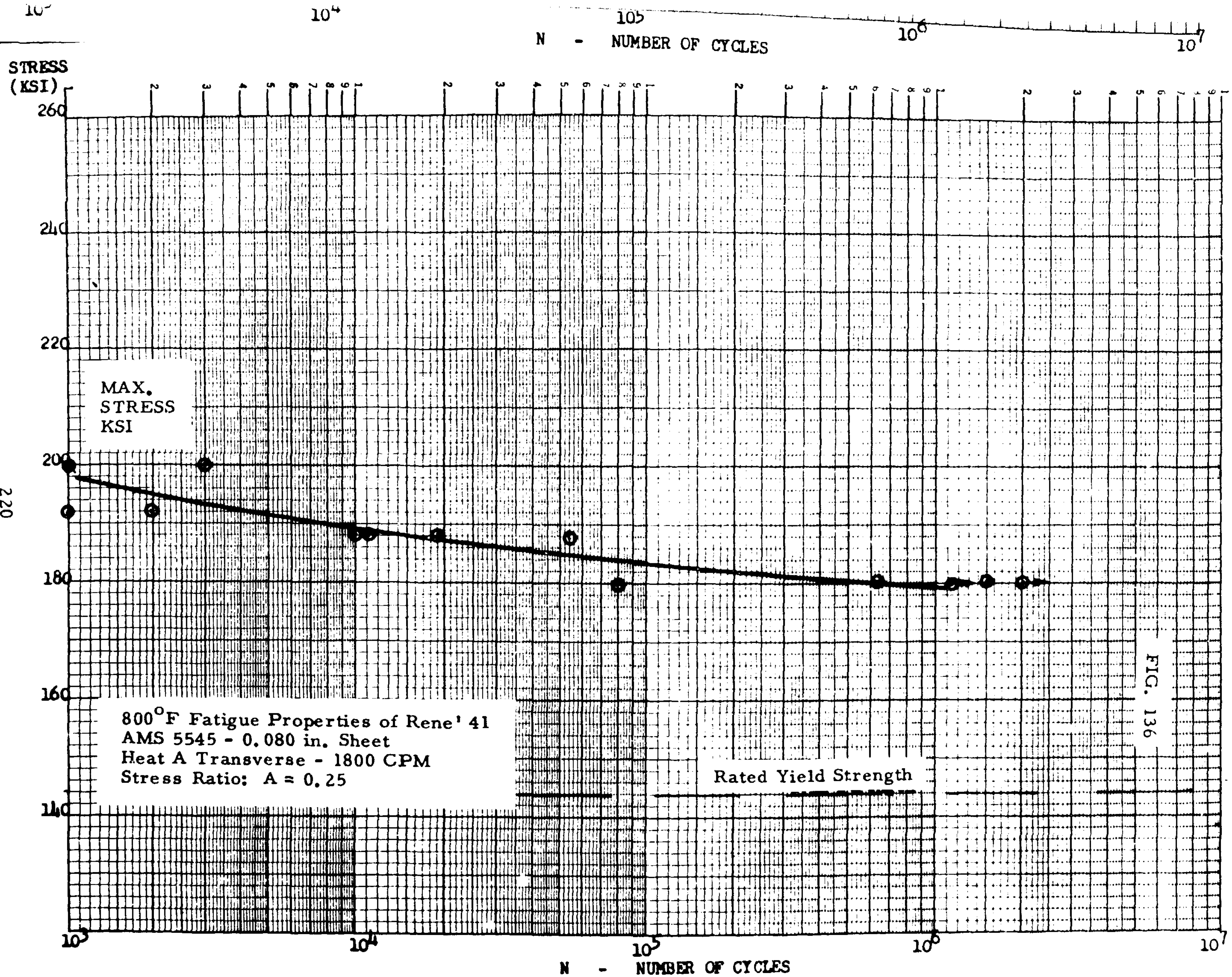

STRESS (KSI)
230
210
190
170
150
130
110
Rated Yield Strength
MAX. STRESS KSI
Room Temperature Fatigue Properties of Rene' 41
AMS 5545 - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 135



N - NUMBER OF CYCLES
STRESS (KSI)
260
240
220
200
180
160
140
MAX. STRESS KSI
800°F Fatigue Properties of Rene' 41
AMS 5545 - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
Rated Yield Strength
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 136

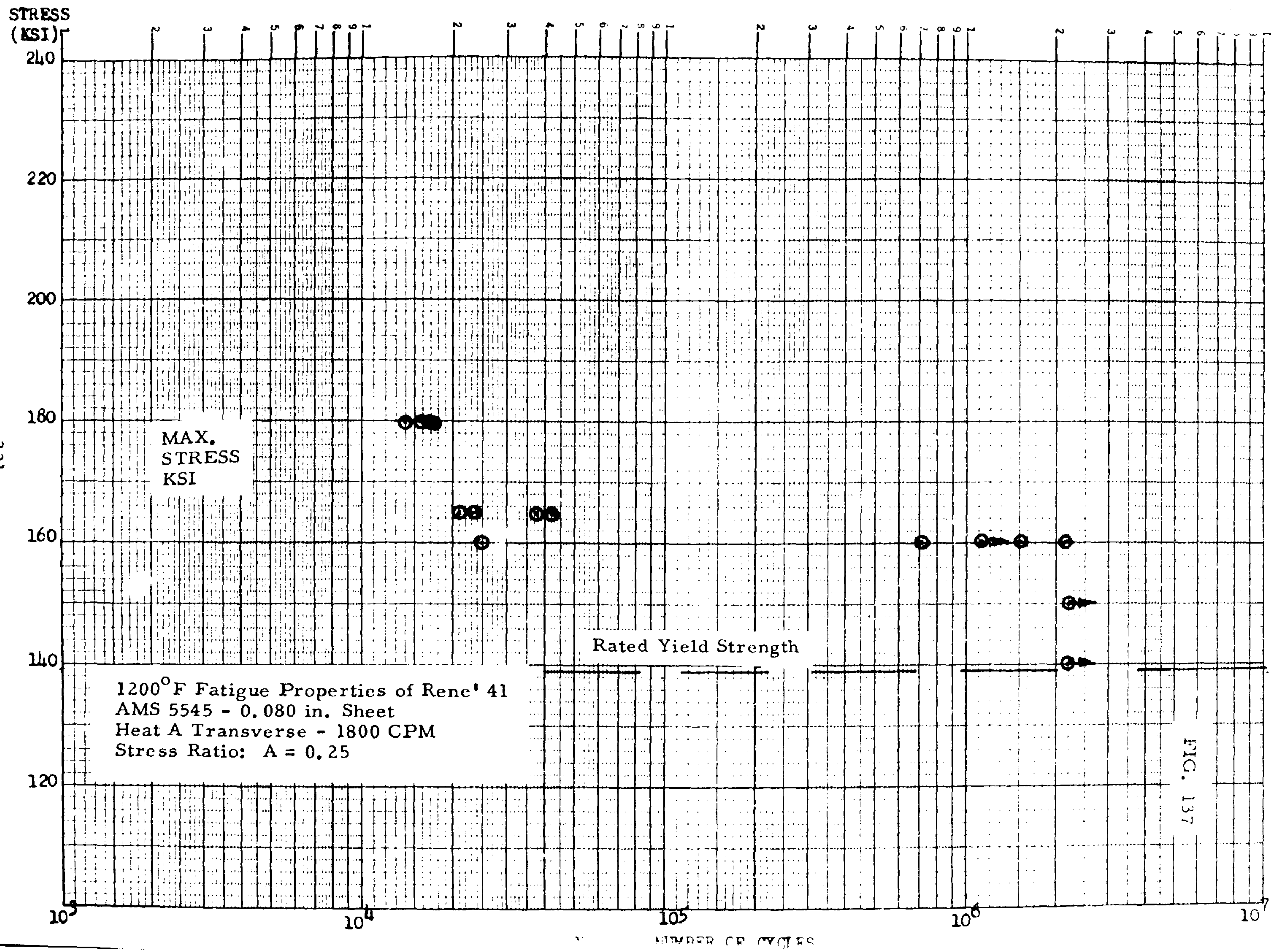

STRESS (KSI)
240
220
200
180
160
140
120
MAX. STRESS KSI
Rated Yield Strength
1200°F Fatigue Properties of Rene' 41
AMS 5545 - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^3
10^4
10^5
10^6
10^7

FIG. 137

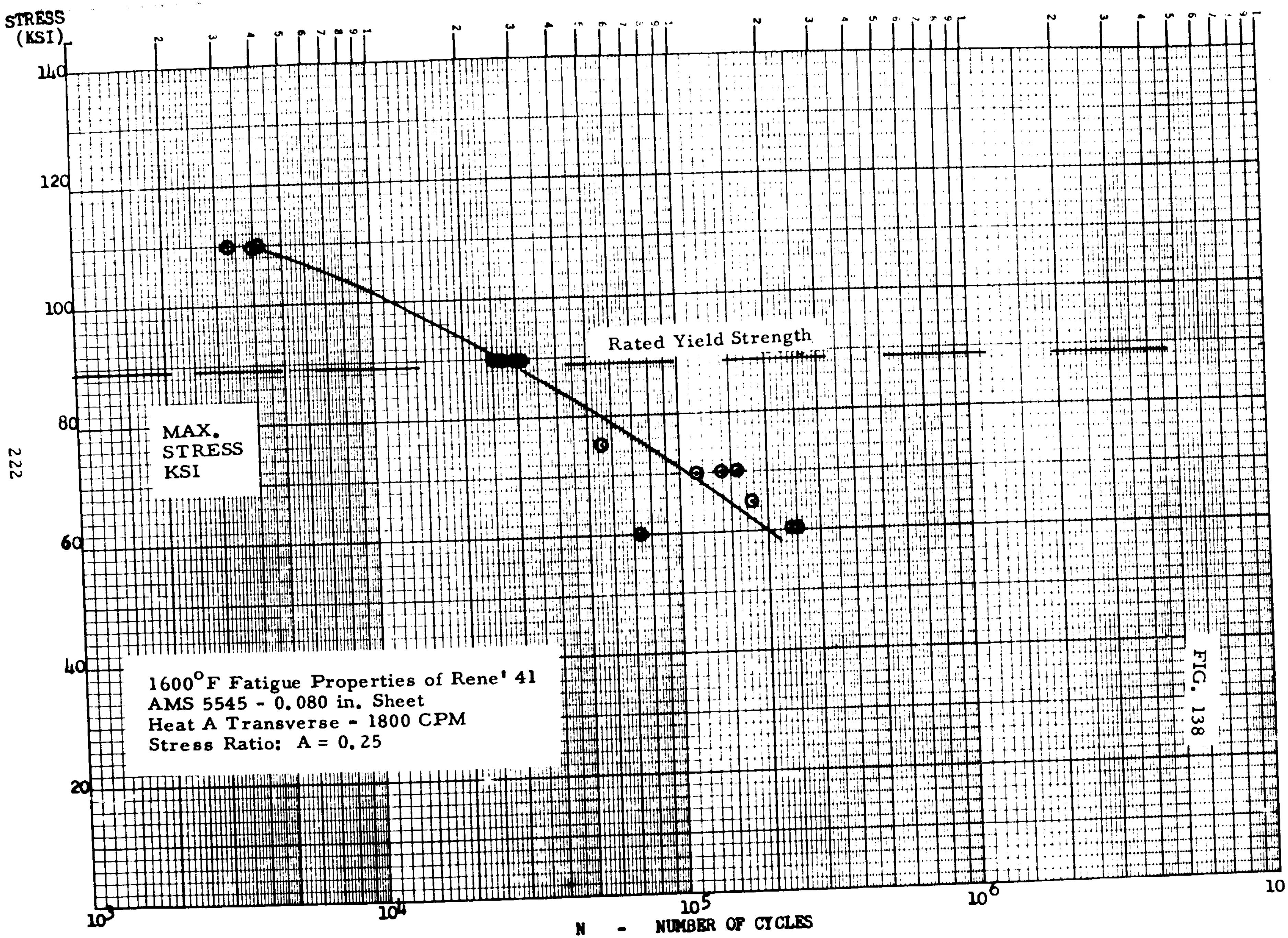
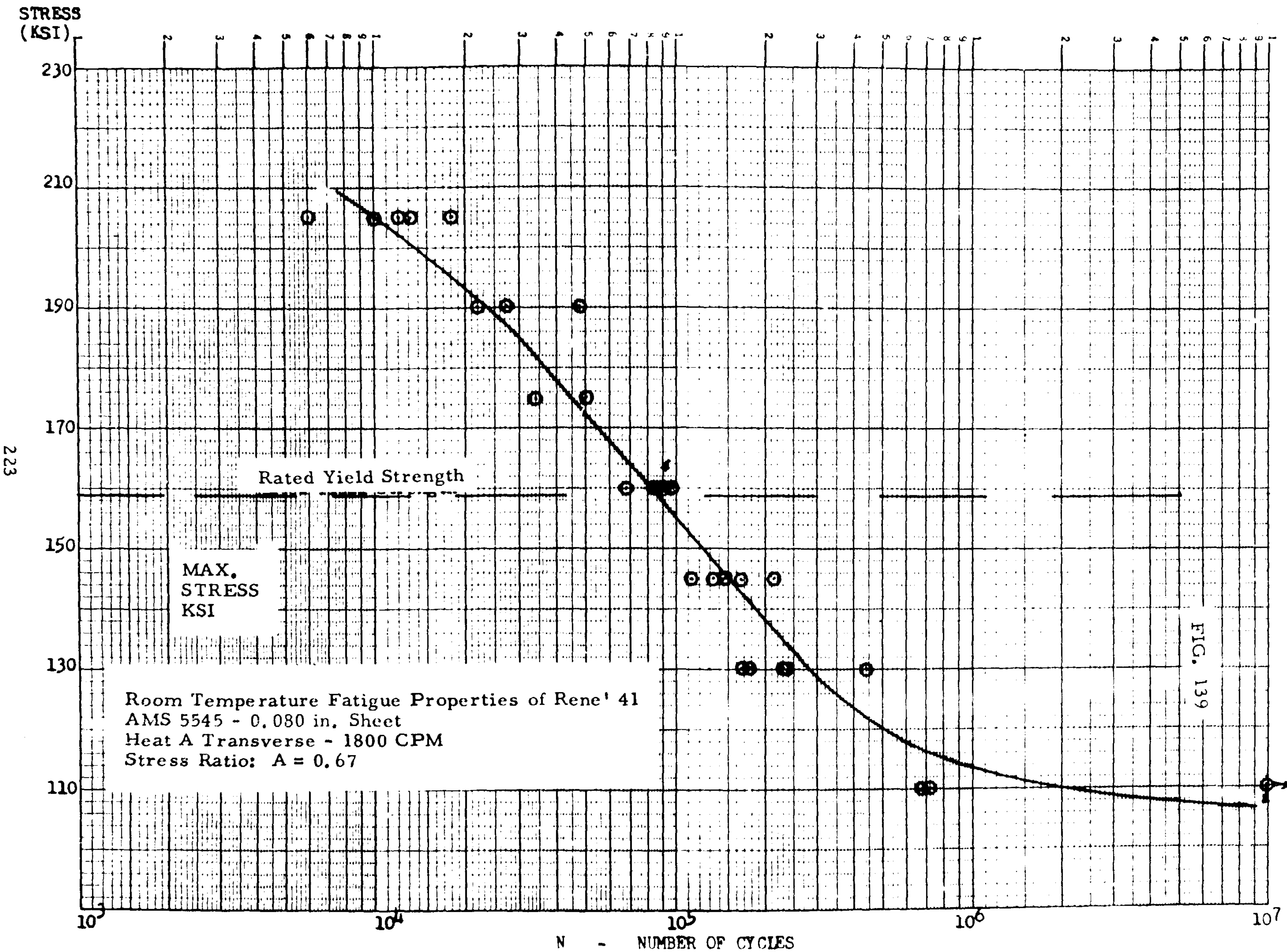

STRESS (KSI)
140
120
100
80
60
40
20
Rated Yield Strength
MAX. STRESS KSI
1600°F Fatigue Properties of Rene' 41
AMS 5545 - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 138



STRESS (KSI)
230
210
190
170
150
130
110
Rated Yield Strength
MAX. STRESS KSI
Room Temperature Fatigue Properties of Rene' 41
AMS 5545 - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 139

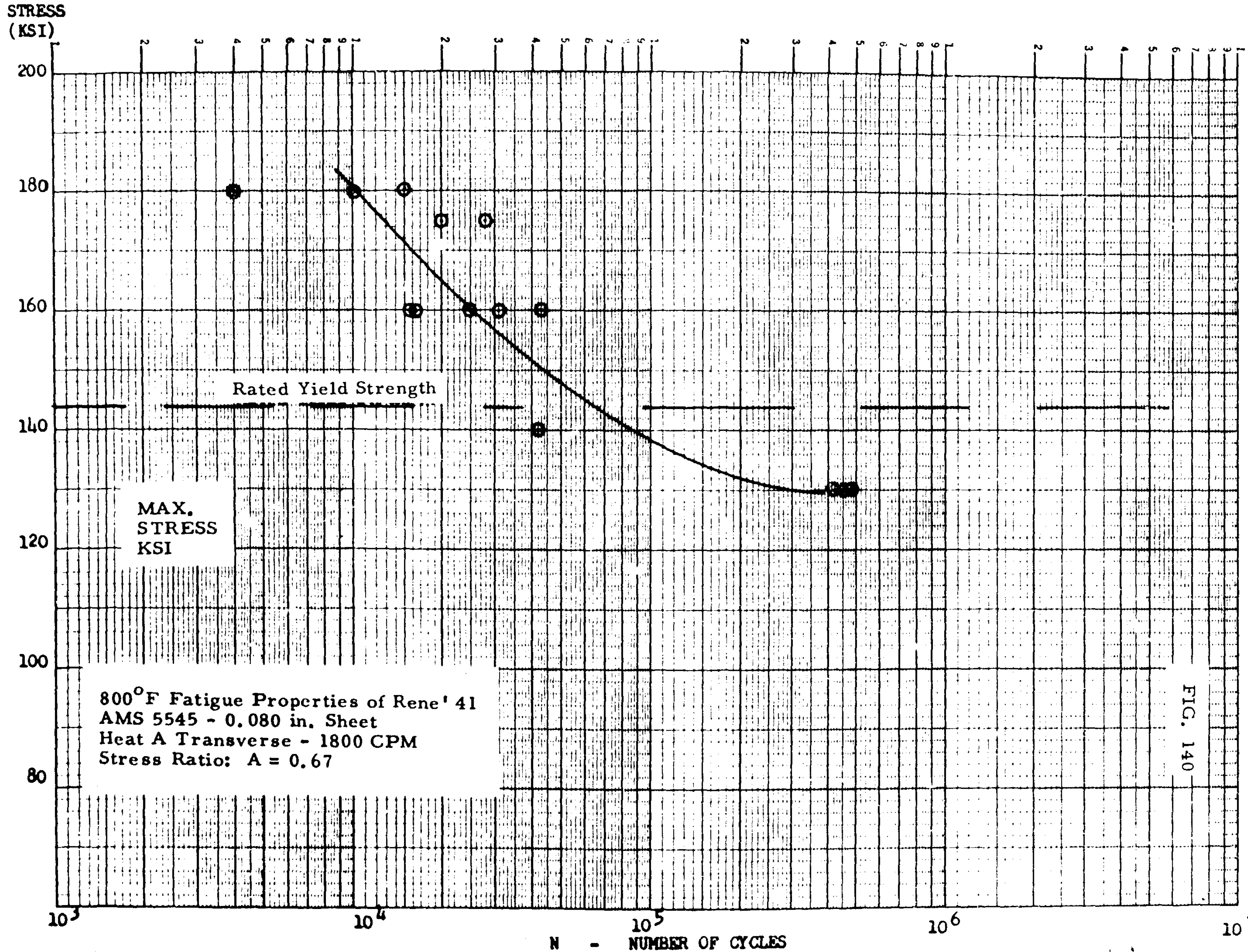
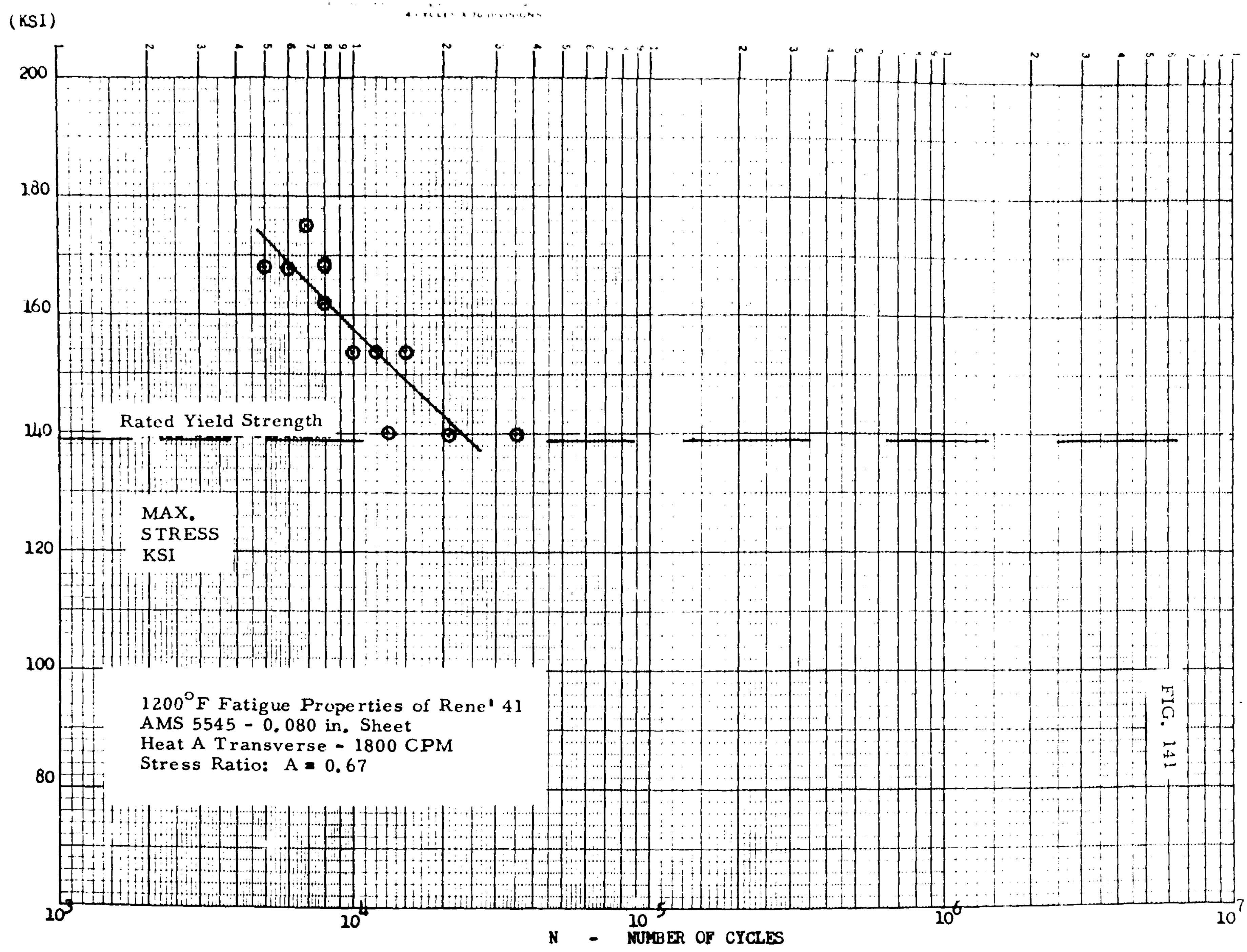

STRESS (KSI)
200
180
160
140
120
100
80
Rated Yield Strength
MAX. STRESS KSI
800°F Fatigue Properties of Rene' 41
AMS 5545 - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 140



(KSI)
200
180
160
140
120
100
80
Rated Yield Strength
MAX.
STRESS
KSI
1200°F Fatigue Properties of Rene' 41
AMS 5545 - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 141

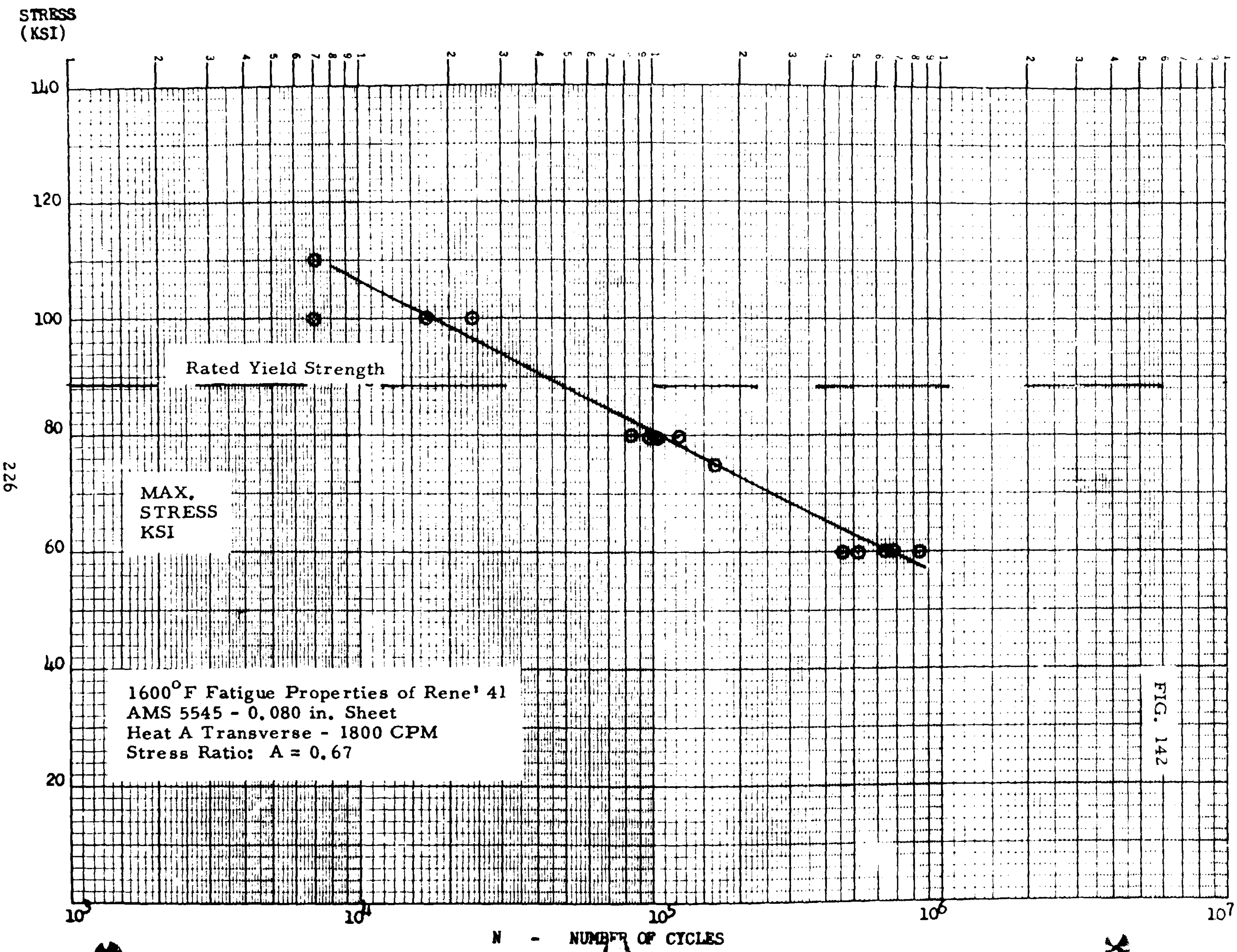
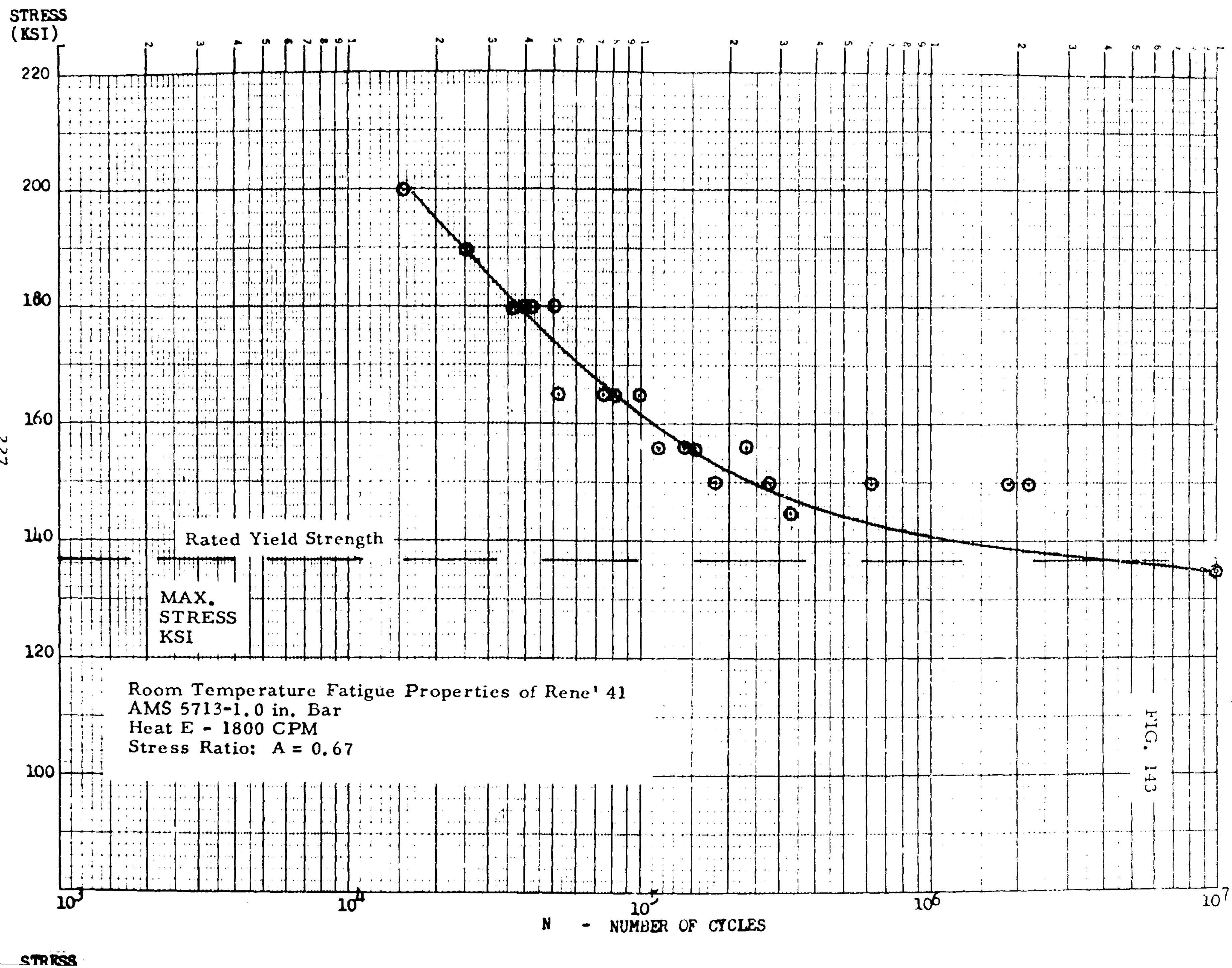
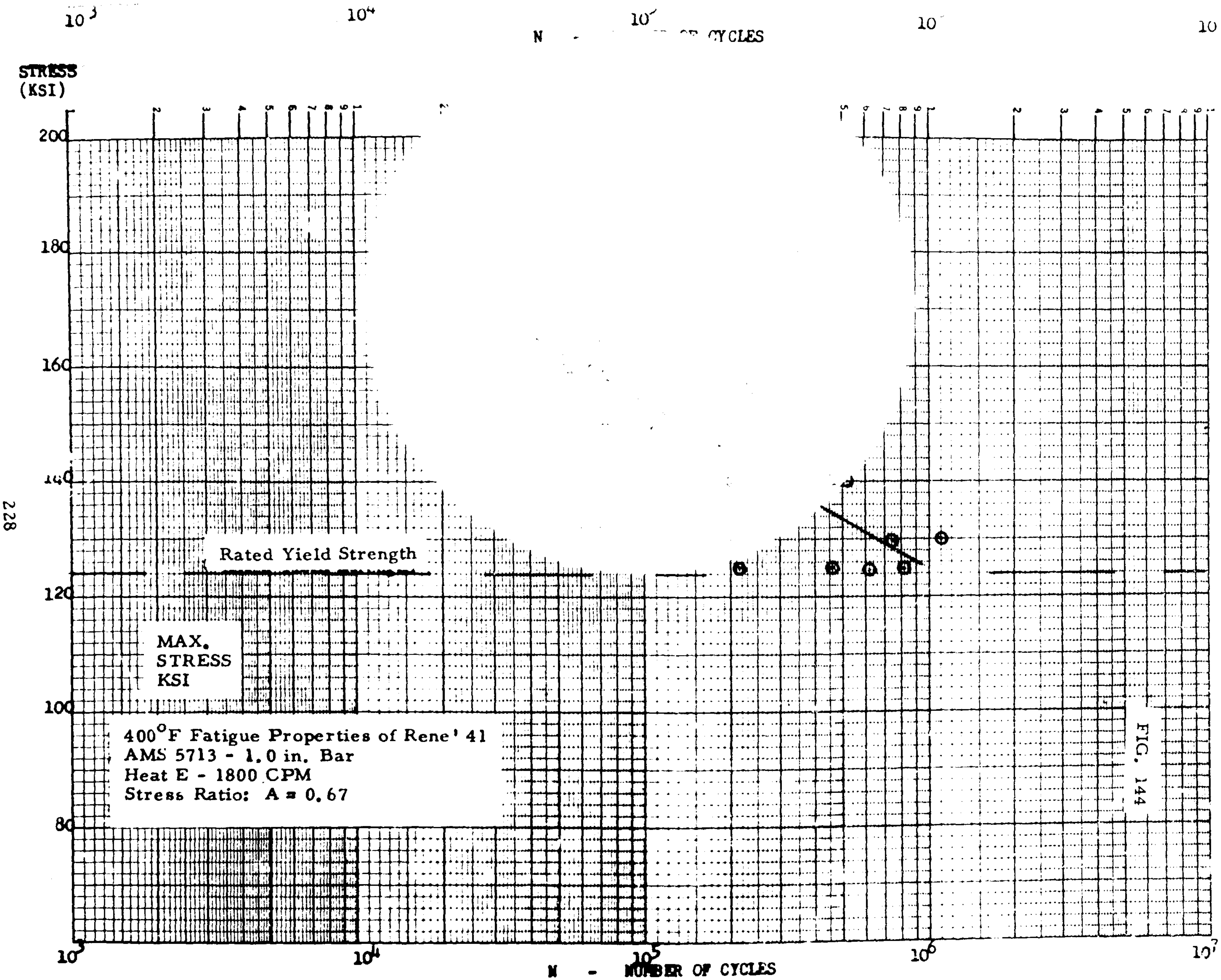

STRESS (KSI)
140
120
100
80
60
40
20
Rated Yield Strength
MAX. STRESS KSI
1600°F Fatigue Properties of Rene' 41
AMS 5545 - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 142


STRESS
(KSI)
220
200
180
160
140
120
100
Rated Yield Strength
MAX.
STRESS
KSI
Room Temperature Fatigue Properties of Rene' 41
AMS 5713-1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.67
FIG. 143
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES
STRESS



STRESS (KSI)
200
180
160
140
120
100
80
Rated Yield Strength
MAX. STRESS KSI
400°F Fatigue Properties of Rene' 41
AMS 5713 - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.67
N - NUMBER OF CYCLES

FIG. 144

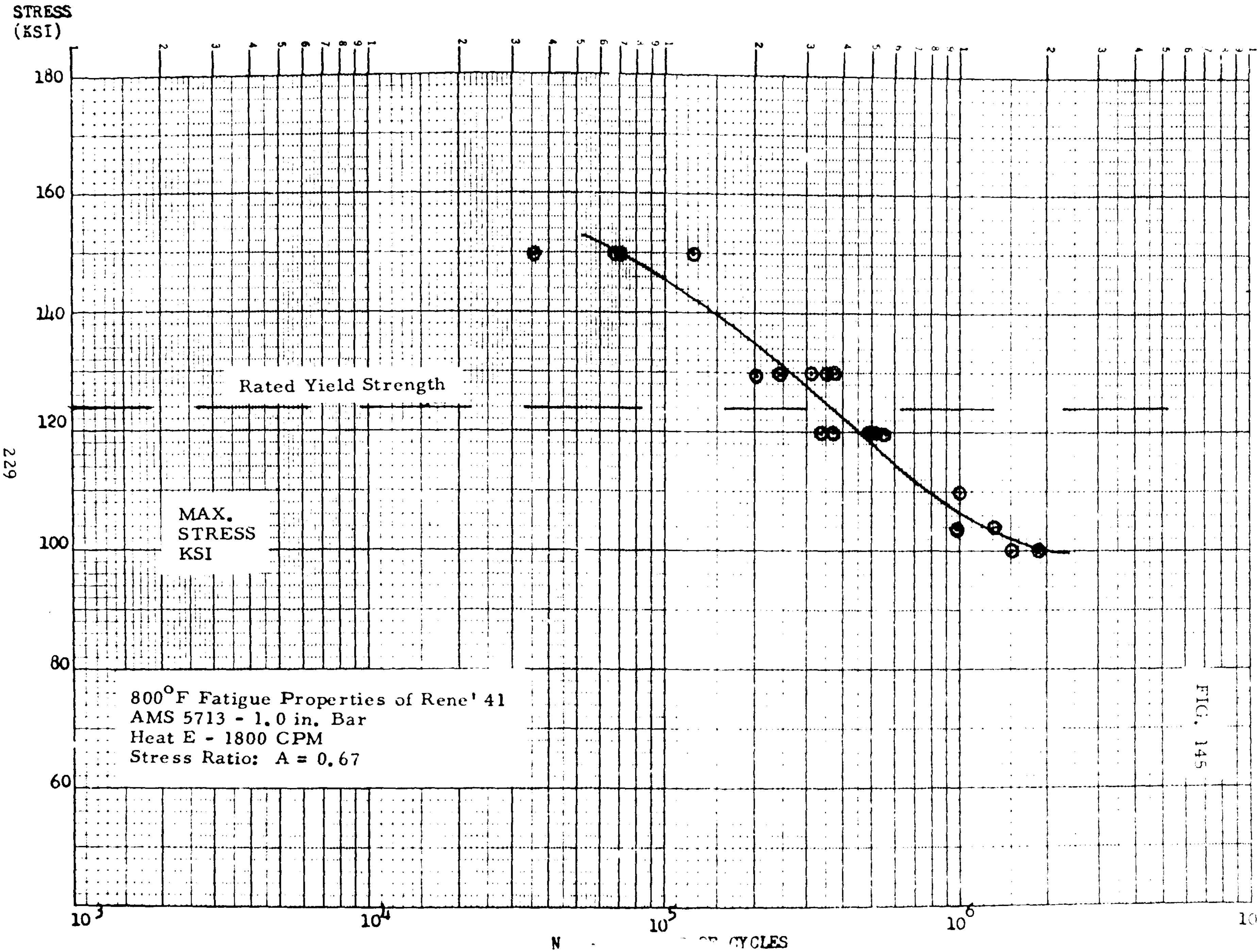

STRESS
(KSI)
180
160
140
120
100
80
60
Rated Yield Strength
MAX.
STRESS
KSI
800°F Fatigue Properties of Rene' 41
AMS 5713 - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.67
10^3
10^4
10^5
10^6

FIG. 145

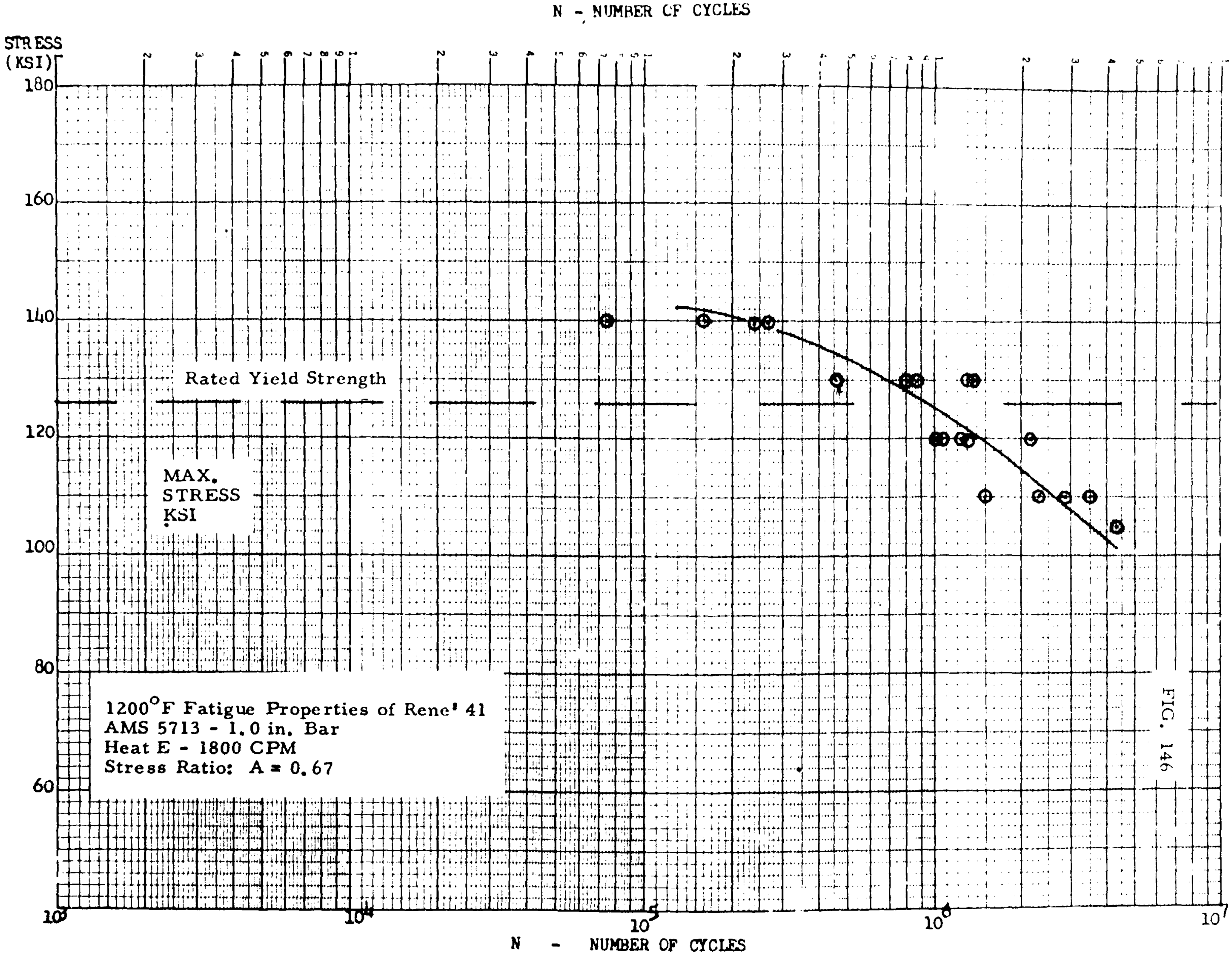

N - NUMBER OF CYCLES
STRESS (KSI)
180
160
140
120
100
80
60
Rated Yield Strength
MAX. STRESS KSI
1200°F Fatigue Properties of Rene' 41
AMS 5713 - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.67
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 146

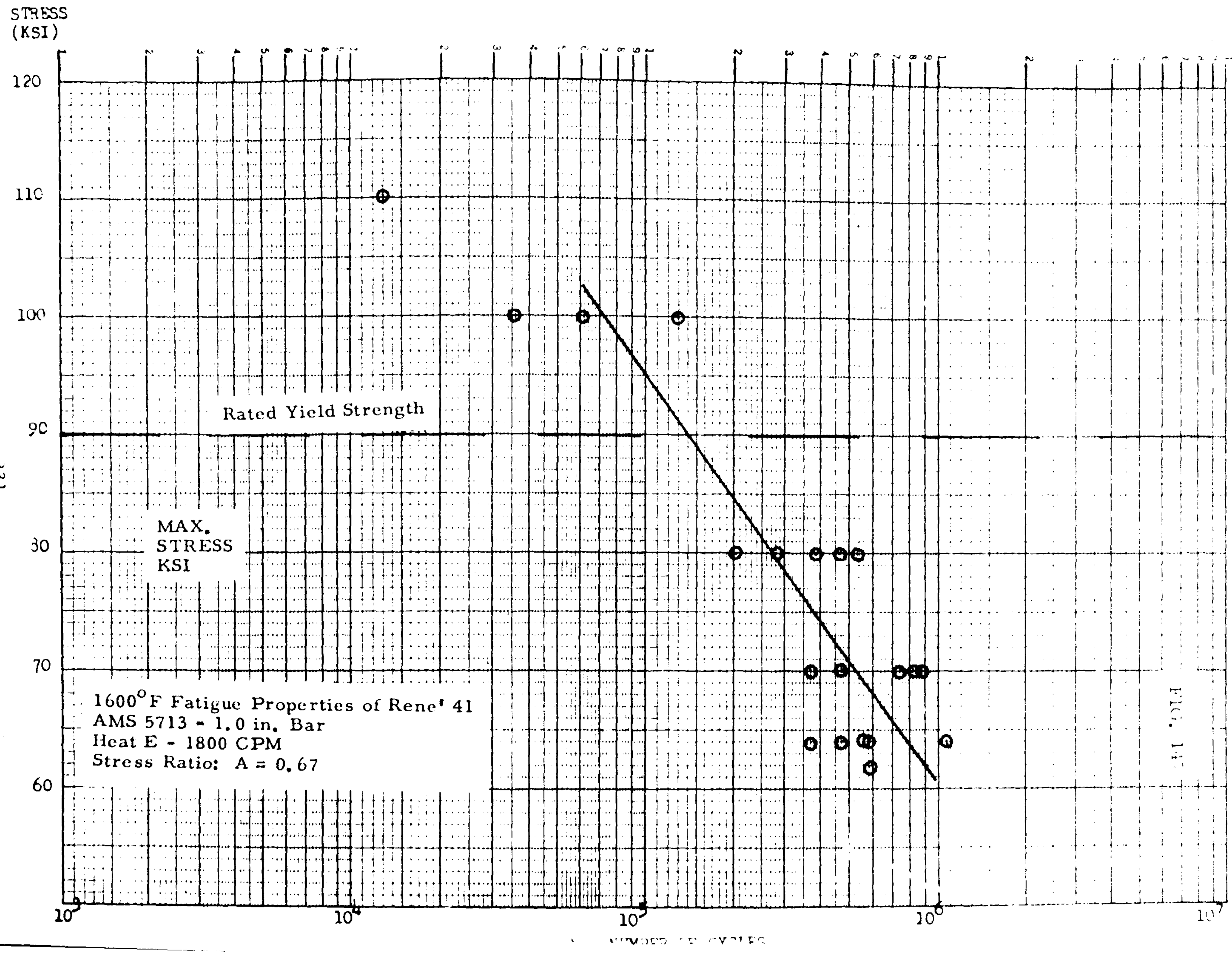

STRESS (KSI)
120
110
100
90
80
70
60
Rated Yield Strength
MAX. STRESS KSI
1600°F Fatigue Properties of Rene' 41
AMS 5713 - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.67
10^3
10^4
10^5
10^6
10^7

FIG. 147

FIGURE
TYPICAL CONSTANT LIFE DIAGRAM FOR FATIGUE BEHAVIOR OF RENE' 41 SHEET MATERIAL AT ROOM TEMPERATURE

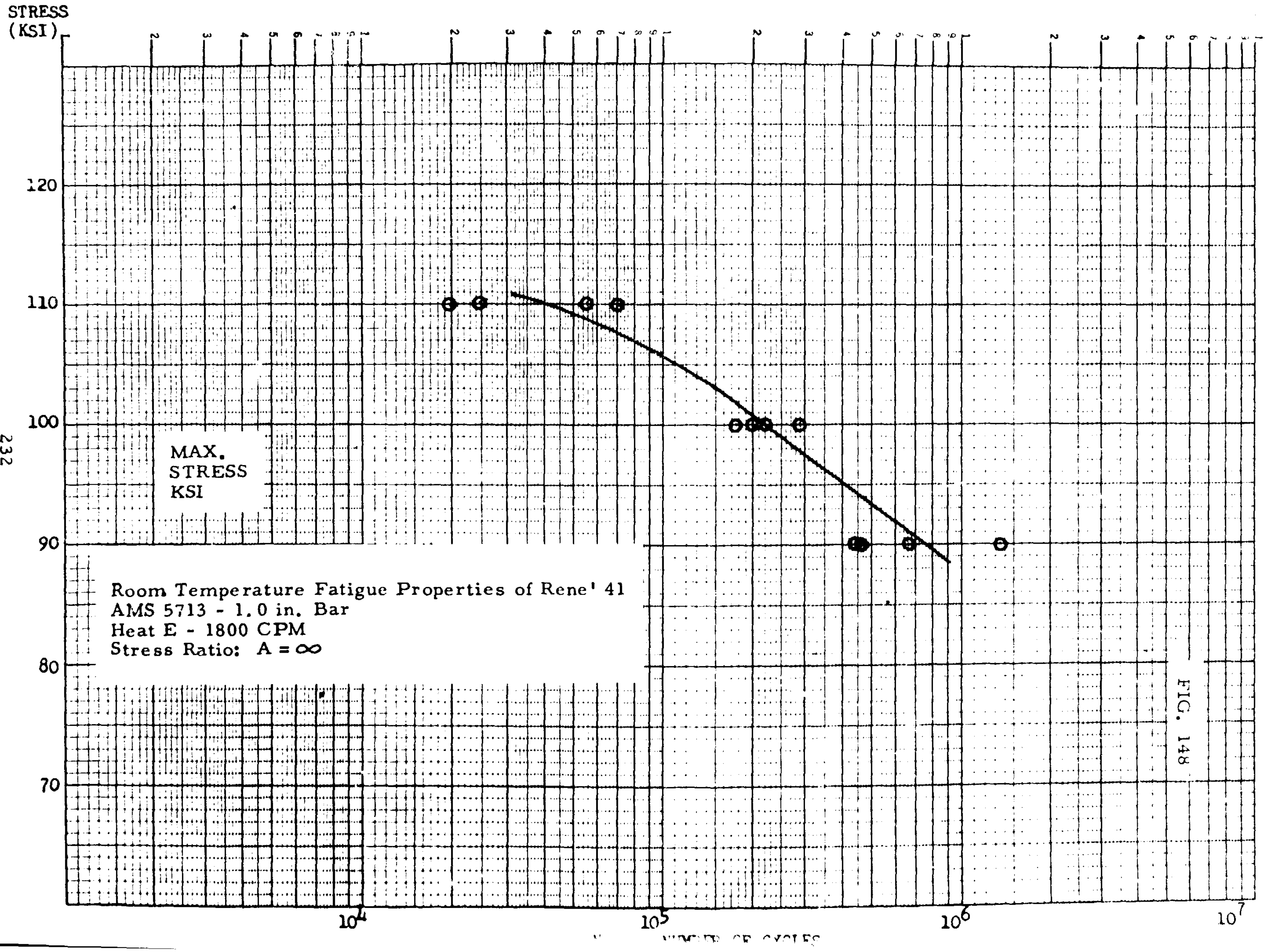
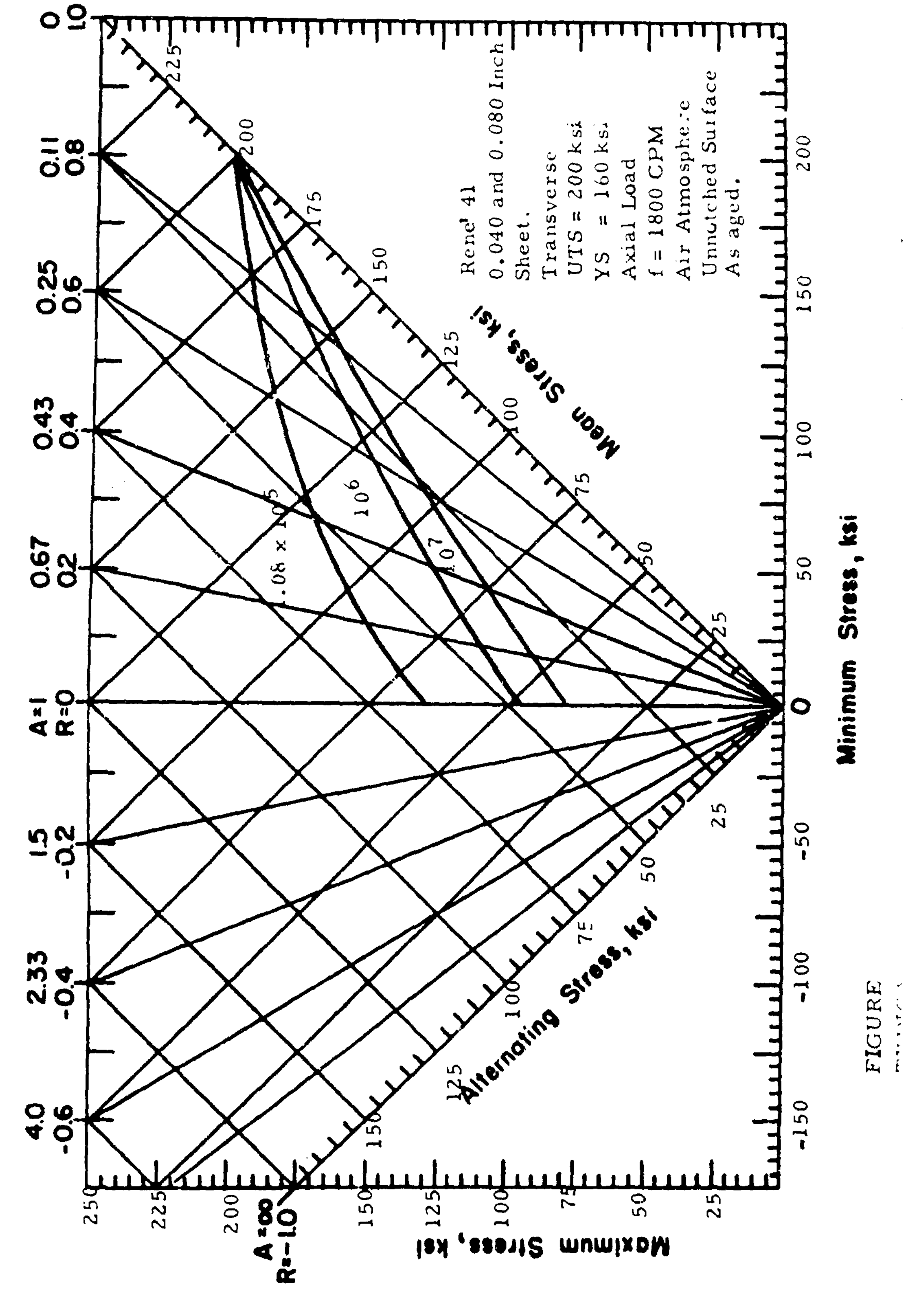


FIG. 149



FIGURE

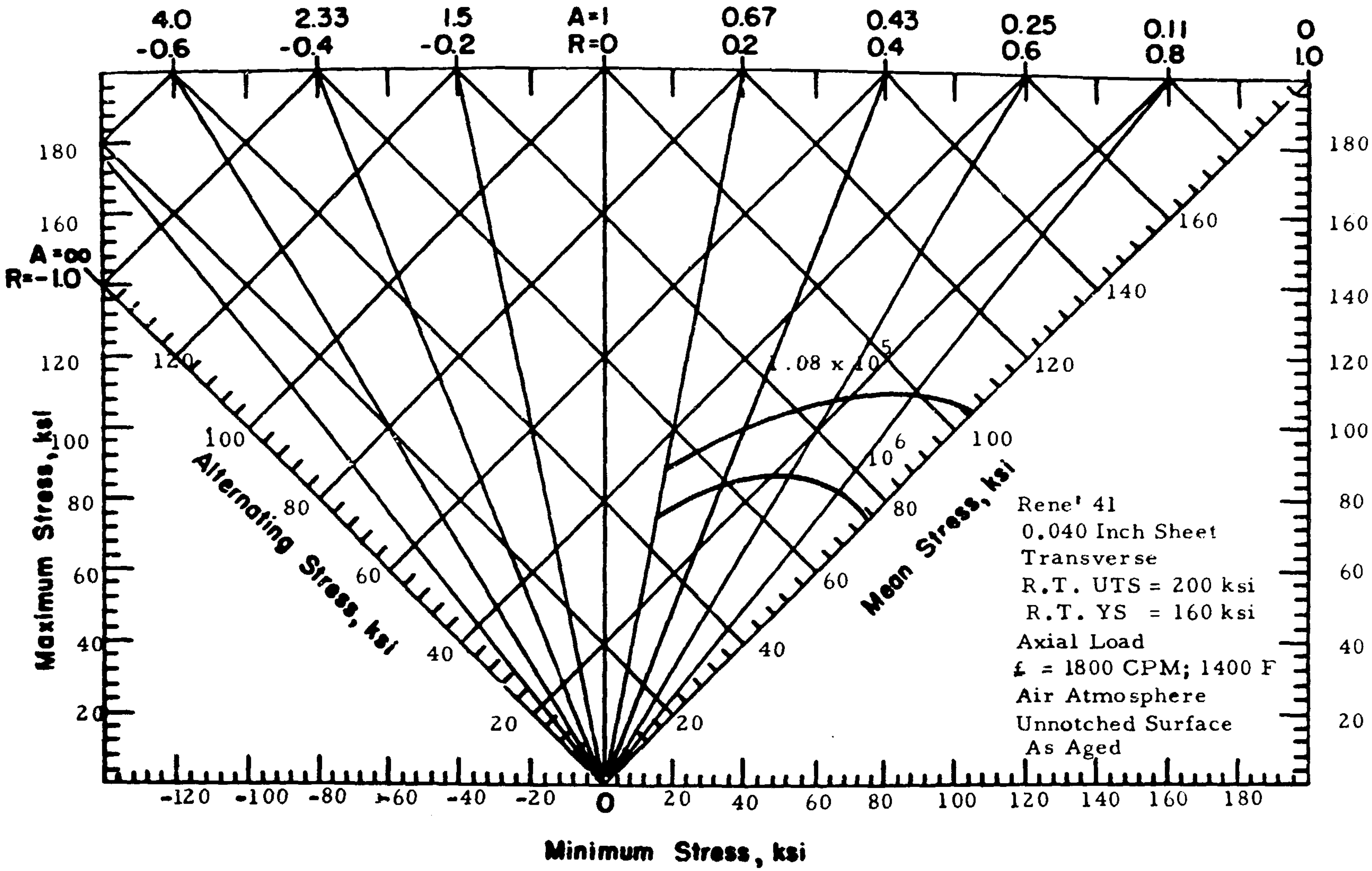


FIGURE TYPICAL CONSTANT LIFE DIAGRAM FOR FATIGUE BEHAVIOR OF RENE' 41 SHEET MATERIAL AT 1400 F.

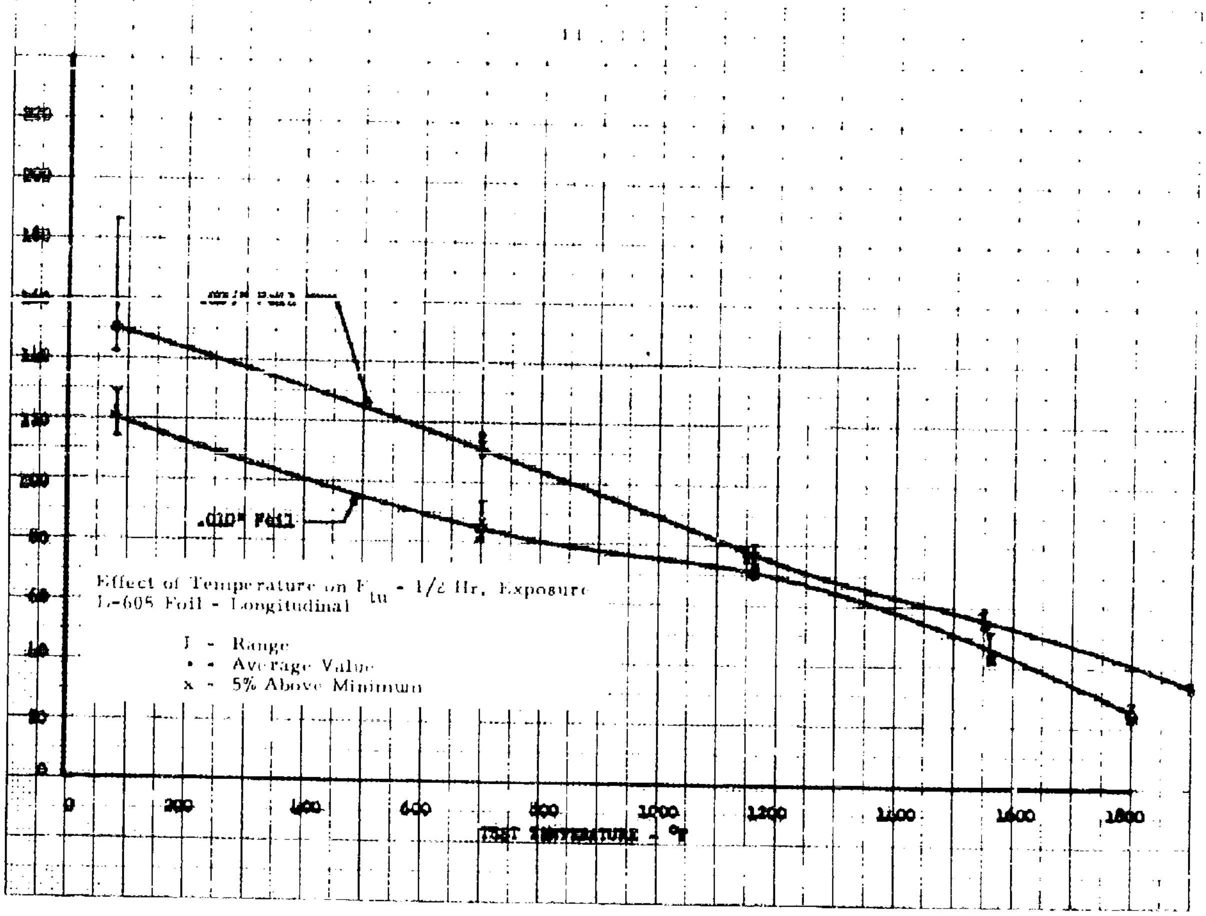
SECTION VII - TEST RESULTS, TABLES AND GRAPHS

SECTION 7.2 MATERIAL, L-605

TABLE OF CONTENTS

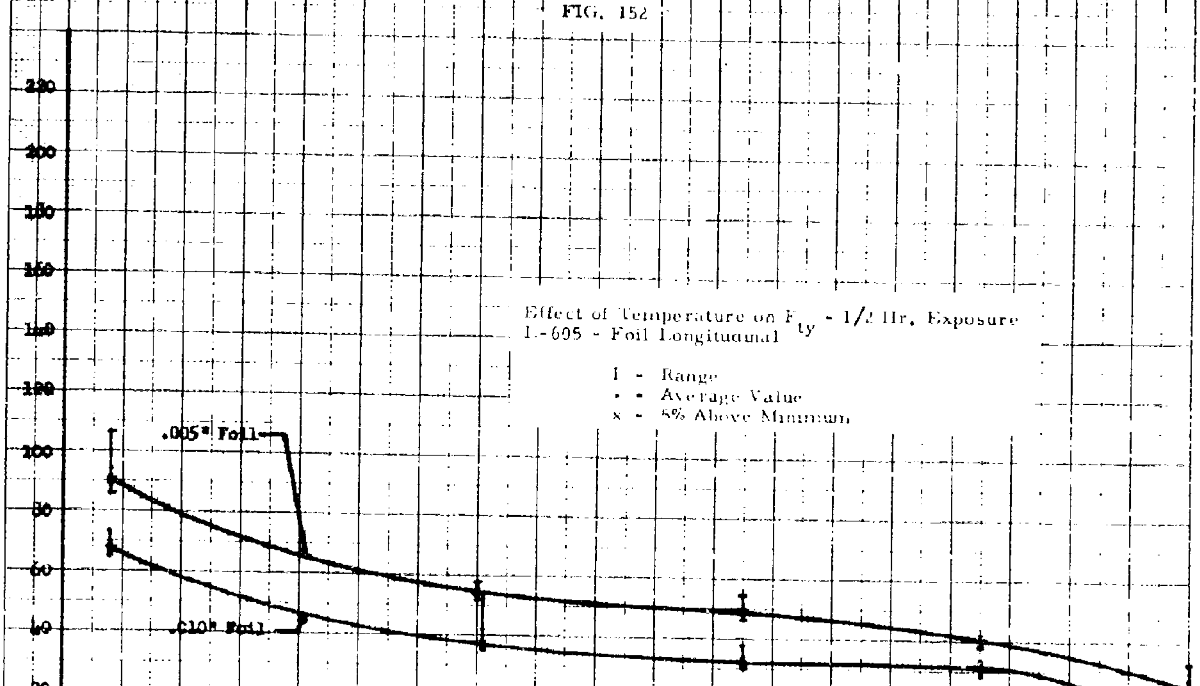
SECTION VII

SECTION 7.2.1 TENSION



Effect of Temperature on F_{tu} - 1/2 Hr. Exposure
L-605 Foil - Longitudinal
I - Range
• - Average Value
x - 5% Above Minimum
.010" Foil
F_{tu} - KSI
Test Temperature - °F

FIG. 152



Effect of Temperature on F_{ty} - 1/2 Hr. Exposure
L-605 - Foil Longitudinal
I - Range
• - Average Value
x - 5% Above Minimum
.005" Foil
.010" Foil
F_{ty} - KSI
Test Temperature - °F

FIG. 153

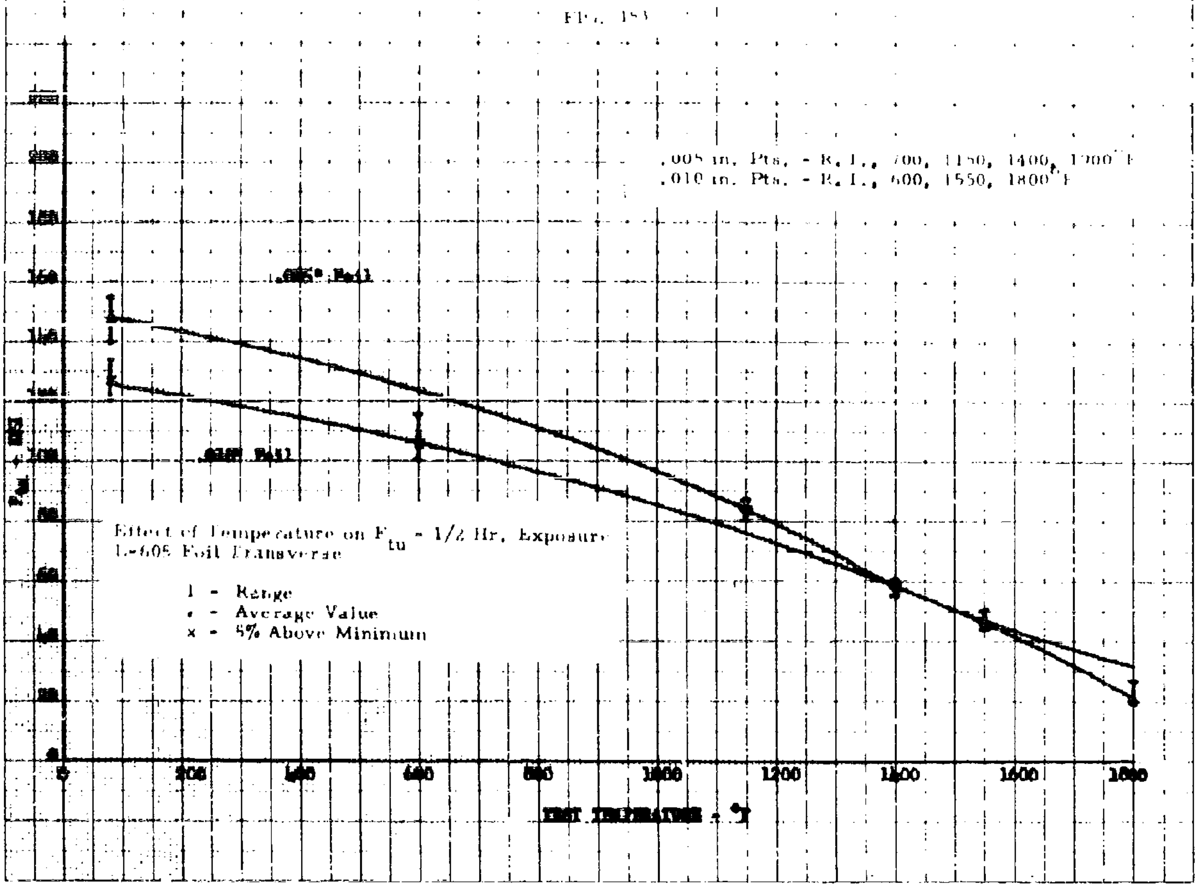


FIG. 154

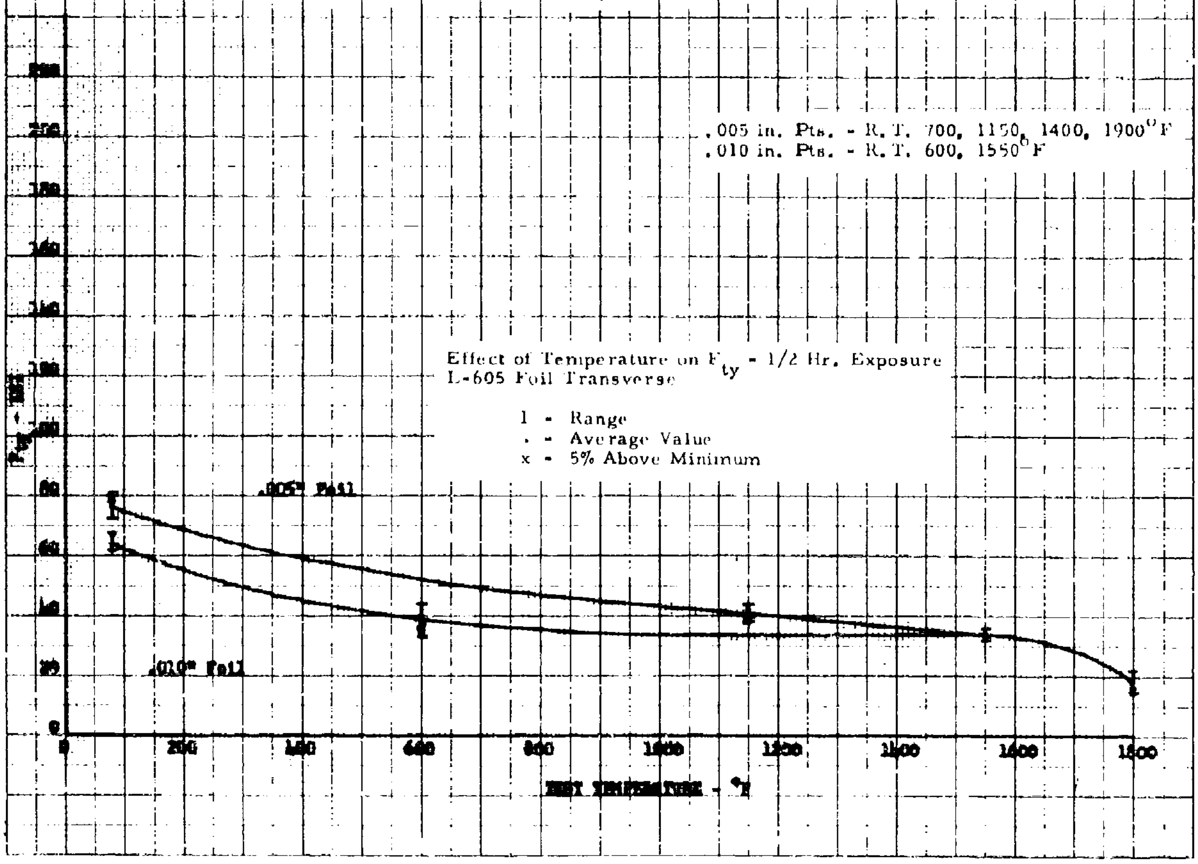


FIG. 155

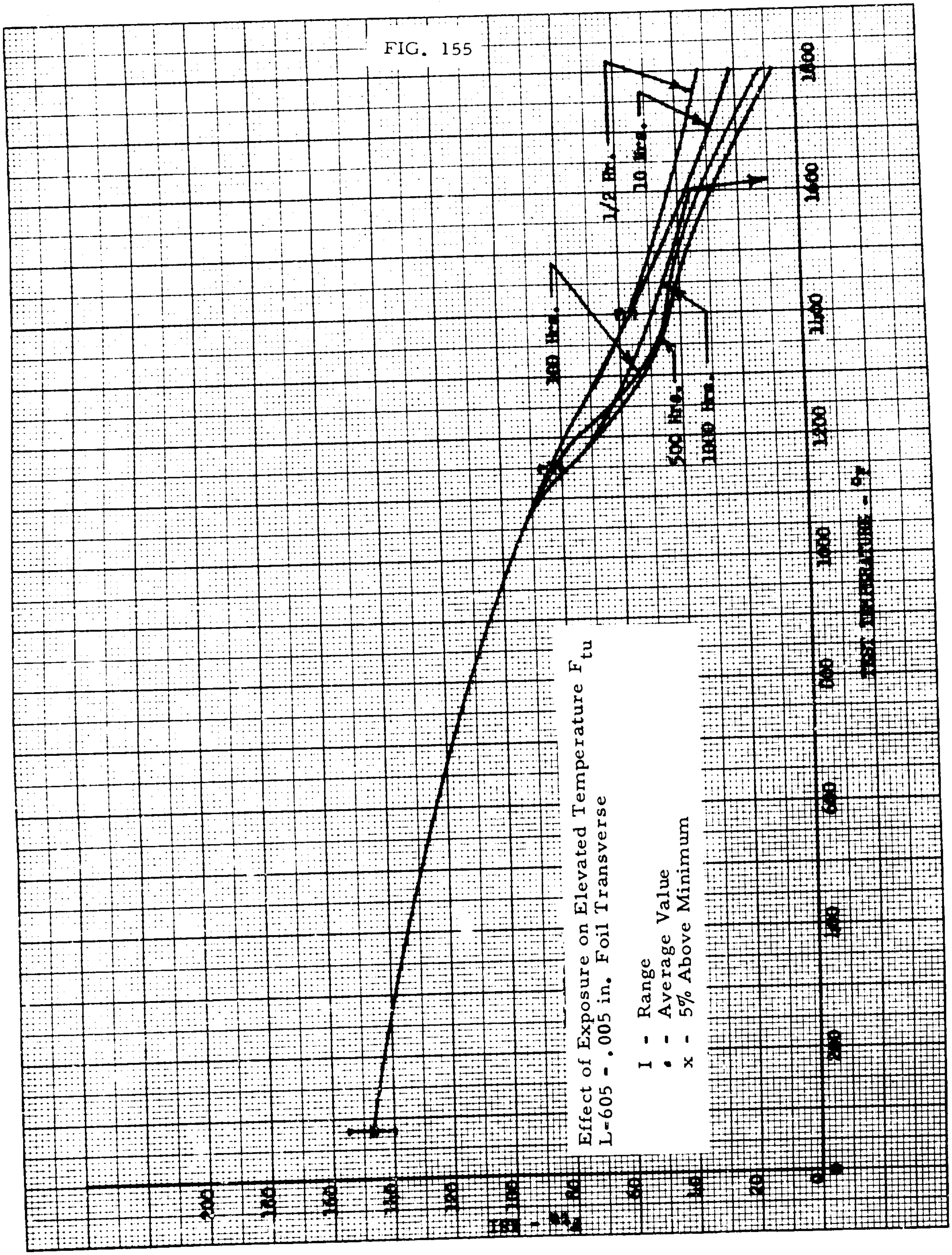

Effect of Exposure on Elevated Temperature F_{tu}
L-605 - .005 in. Foil Transverse
I - Range
• - Average Value
x - 5% Above Minimum
1/2 Hr.
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
TEST TEMPERATURE - °F
0
200
400
600
800
1000
1200
1400
1600
1800
20
40
60
80
100
120
140
160
180
200

FIG. 156

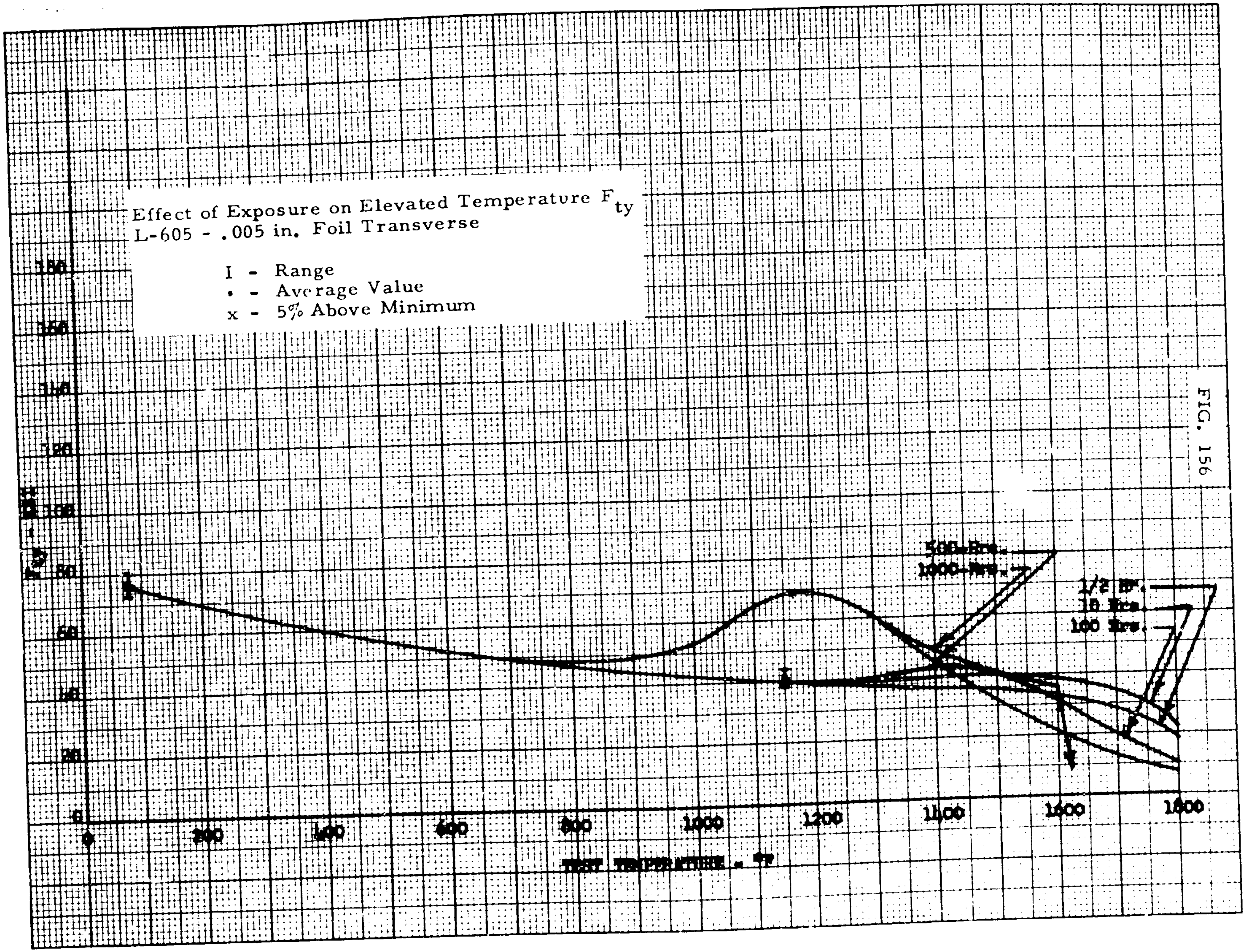

Effect of Exposure on Elevated Temperature F_{ty}
L-605 - .005 in. Foil Transverse
I - Range
• - Average Value
x - 5% Above Minimum
500 Hrs.
1000 Hrs.
1/2 Hr.
10 Hrs.
100 Hrs.
0
20
40
60
80
100
120
140
160
180
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE - °F

FIG. 157

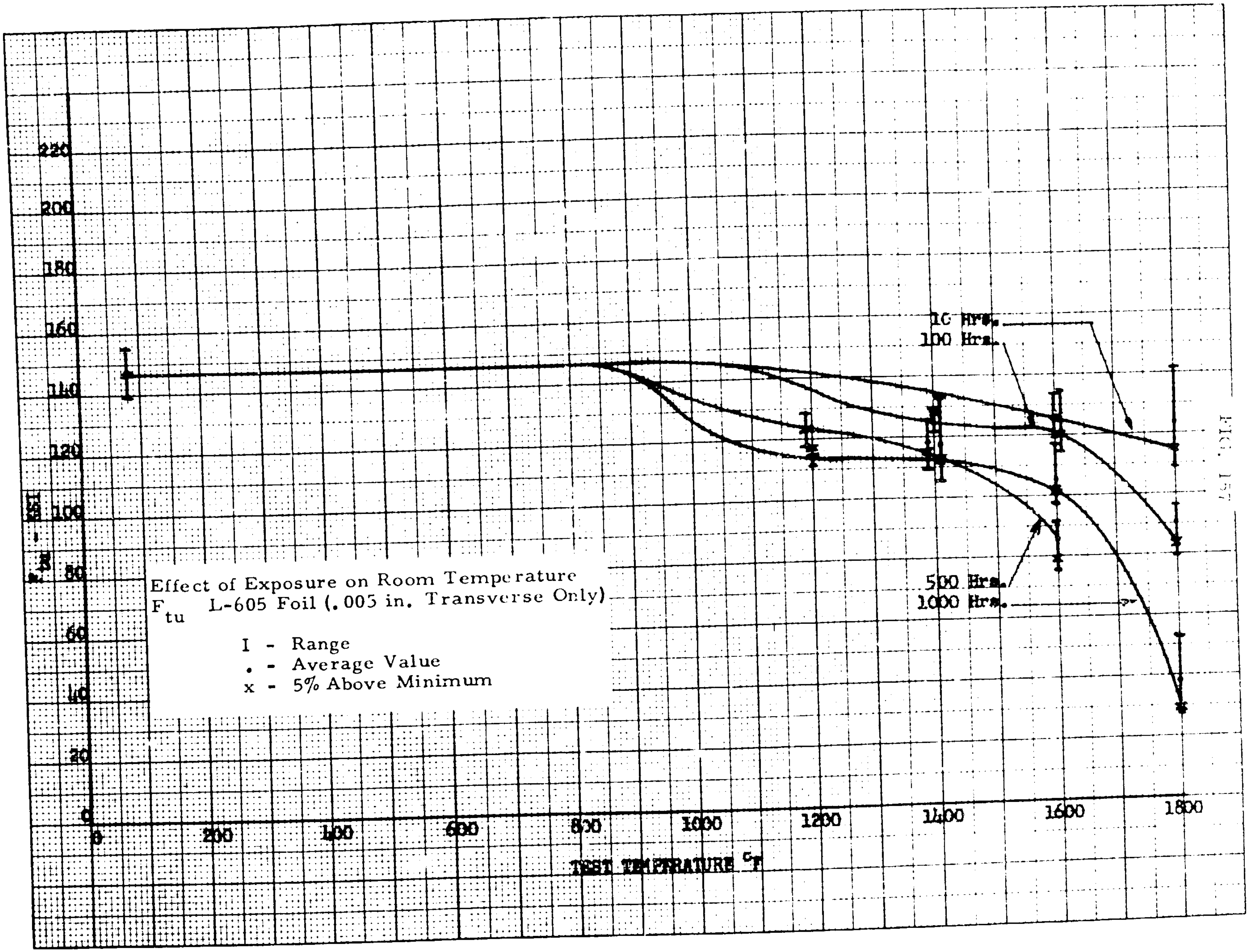
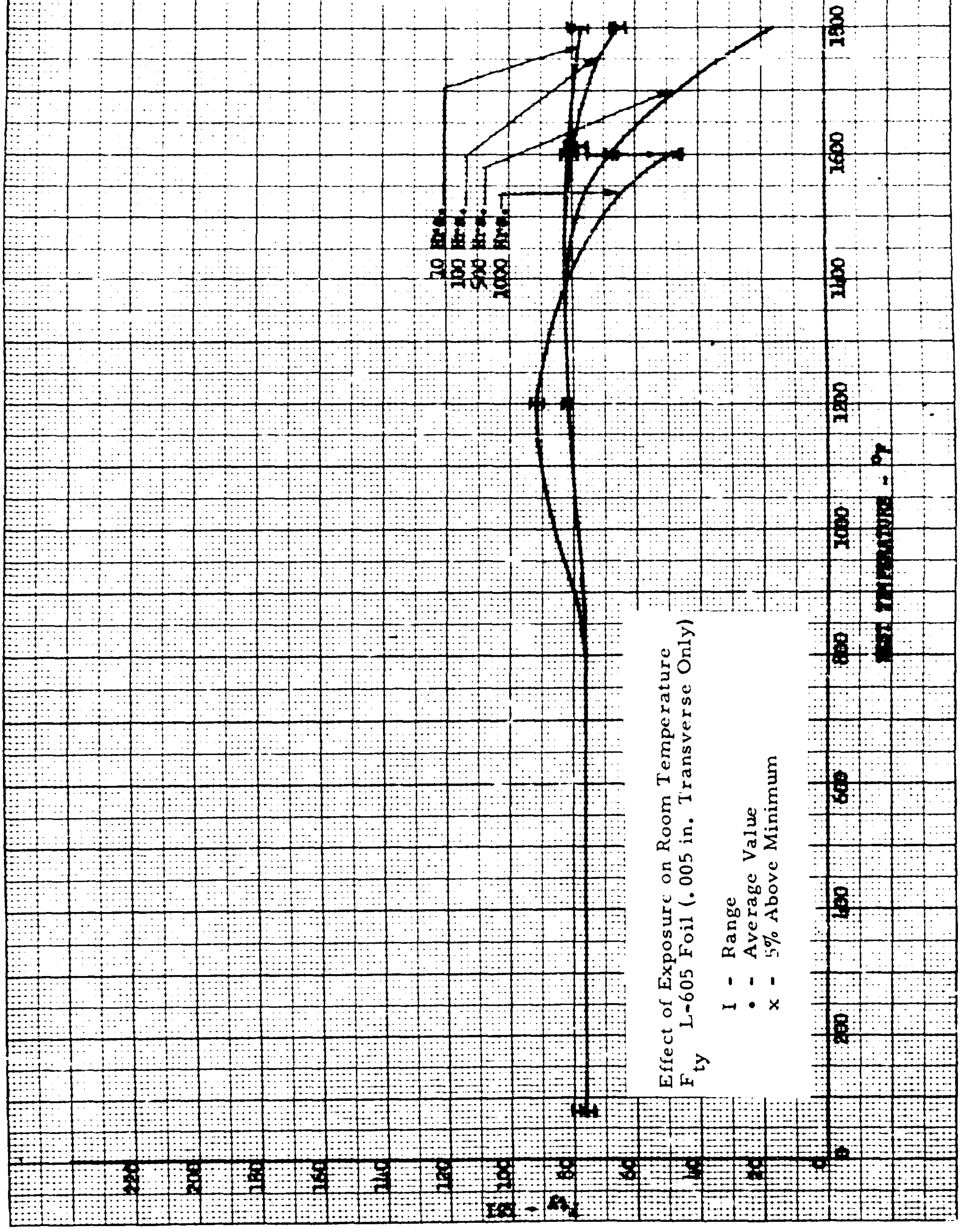
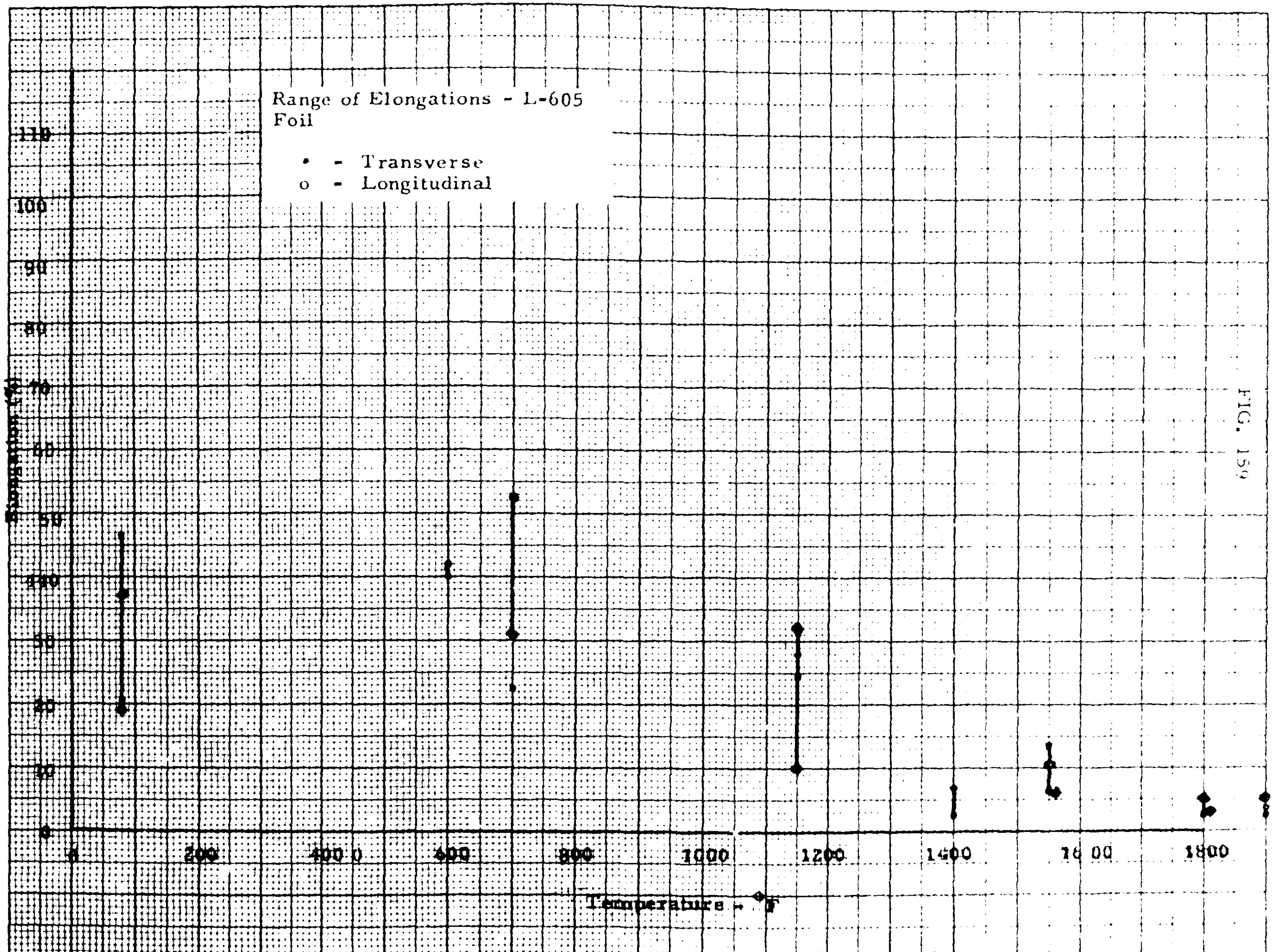

Effect of Exposure on Room Temperature
F_{tu} L-605 Foil (.005 in. Transverse Only)
I - Range
. - Average Value
x - 5% Above Minimum
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
220
200
180
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE °F

FIG. 158



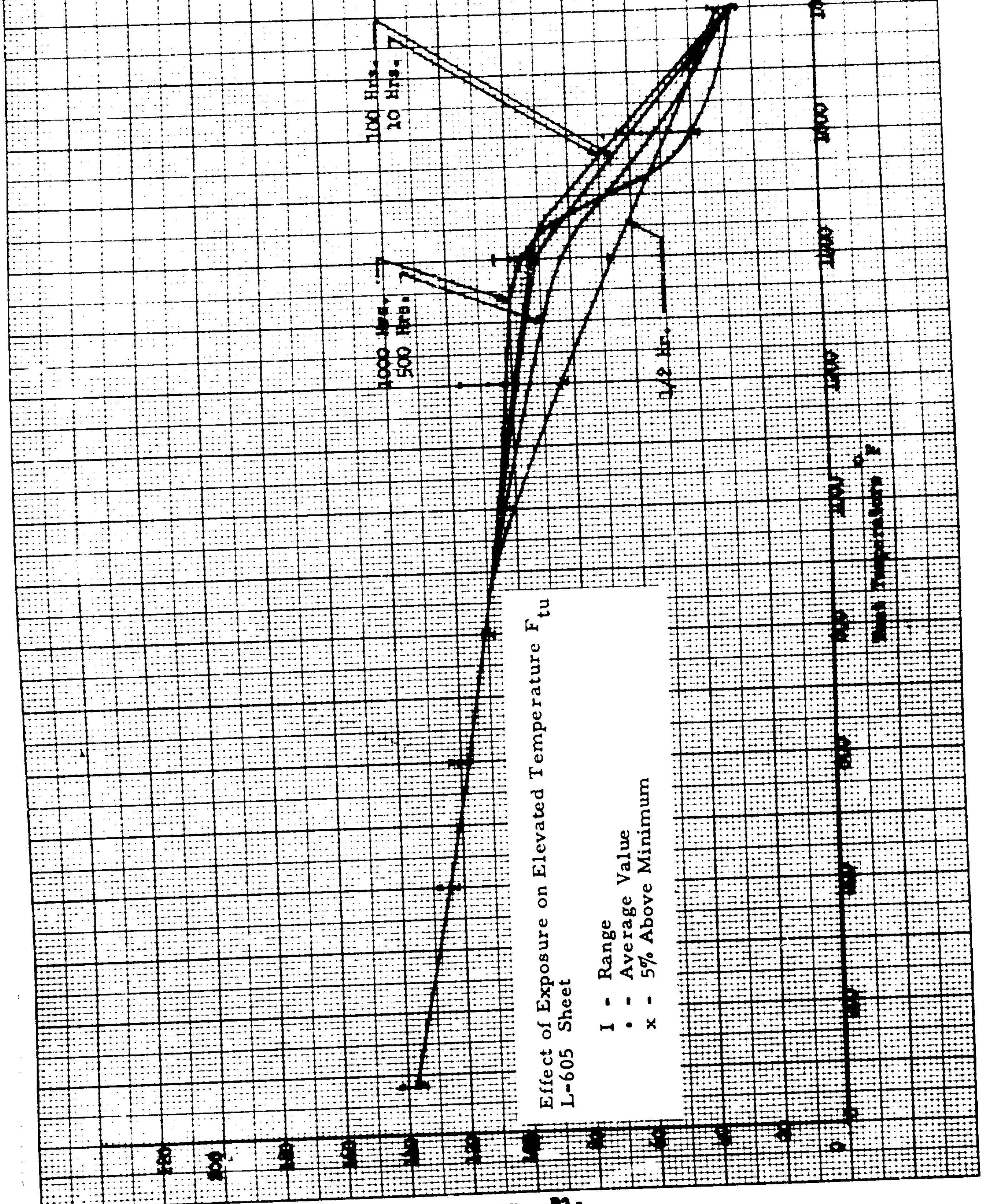
Effect of Exposure on Room Temperature
F_{ty} L-605 Foil (.005 in. Transverse Only)
I - Range
• - Average Value
x - 5% Above Minimum
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
TEST TEMPERATURE - °F
KSI - F_{ty}
0
200
400
600
800
1000
1200
1400
1600
1800
20
40
60
80
100
120
140
160
180
200
220



Range of Elongations - L-605
Foil
• - Transverse
o - Longitudinal
Elongation (%)
110
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
Temperature - °F

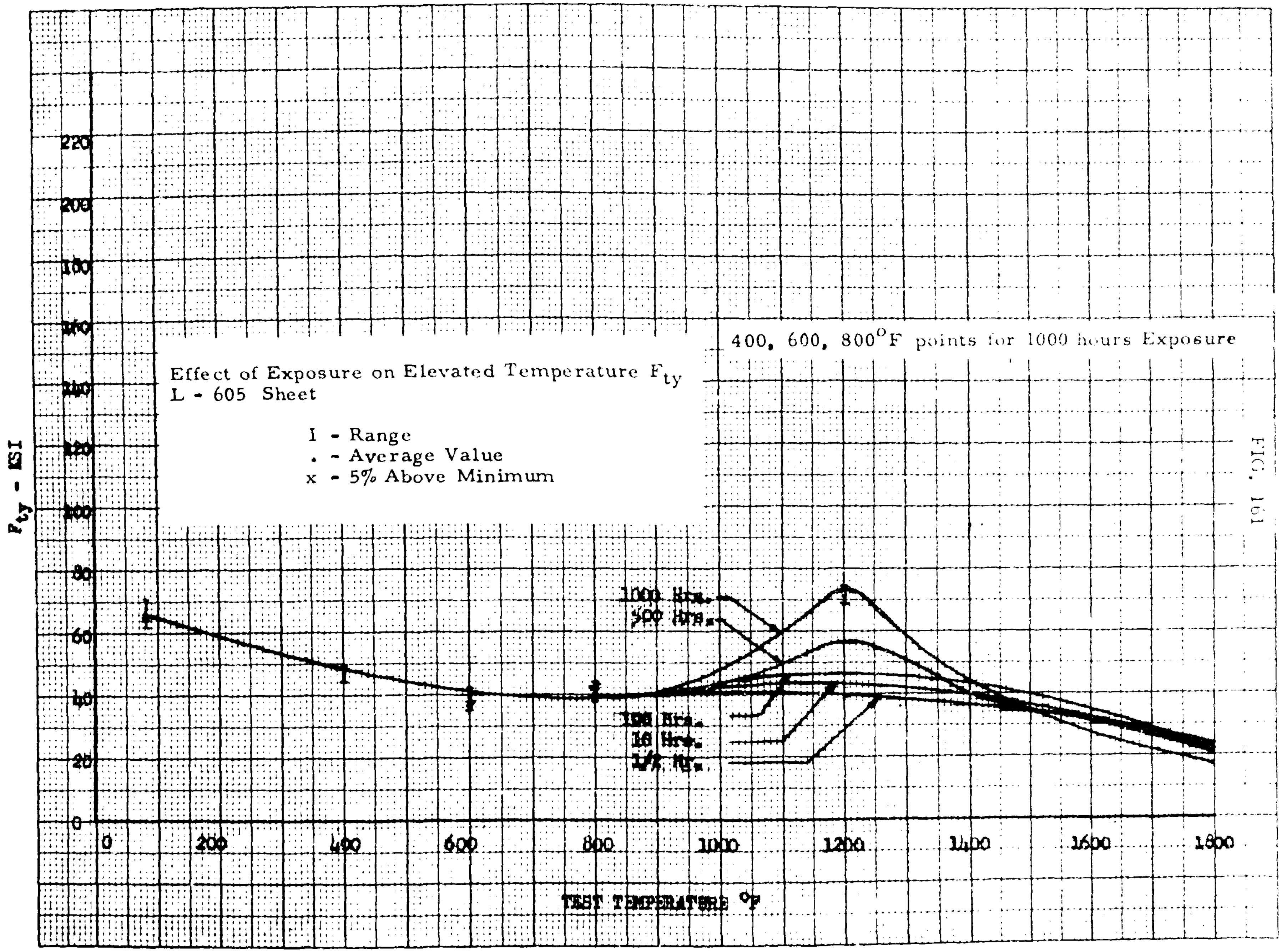
FIG. 159

FIG. 160



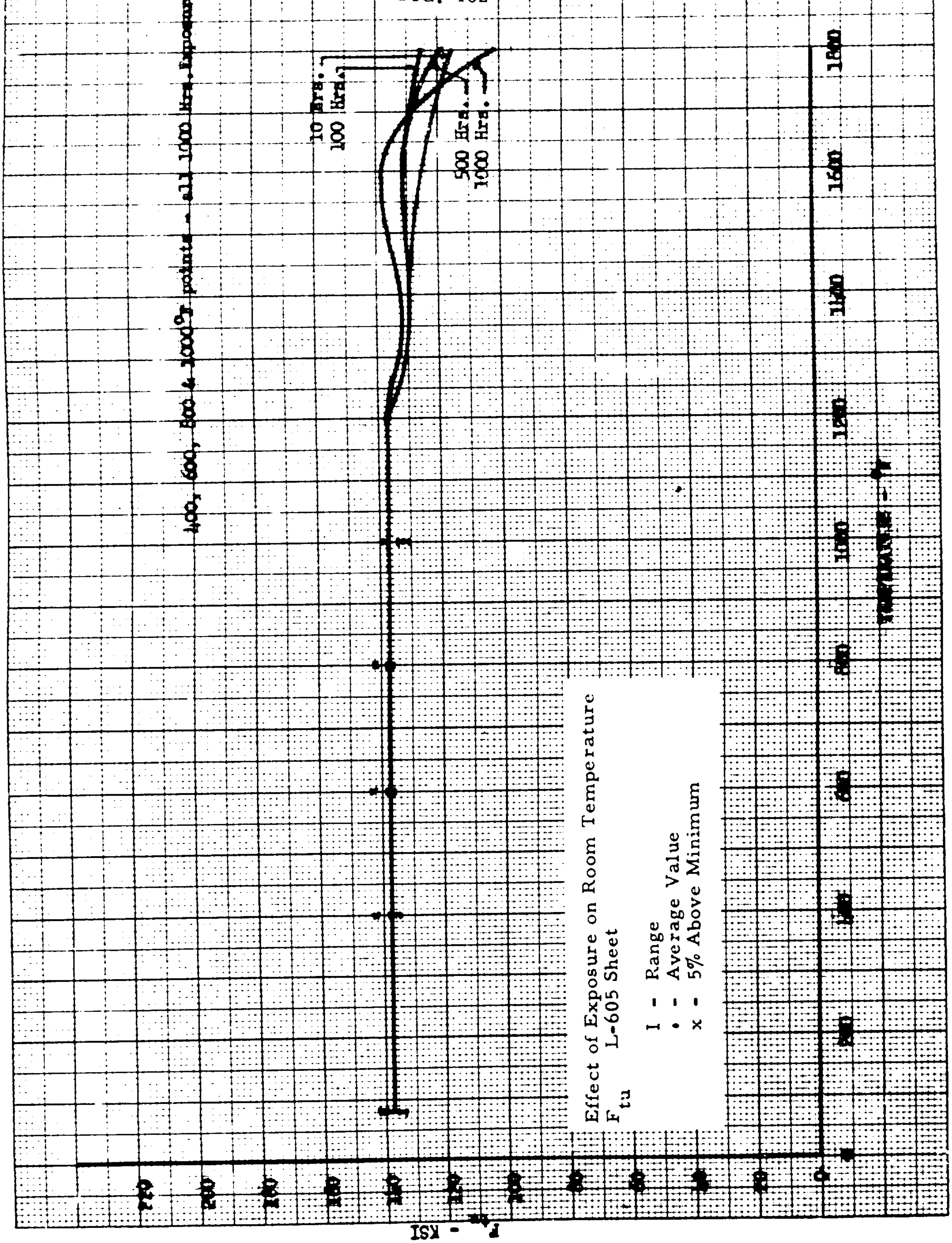
Effect of Exposure on Elevated Temperature F_{tu}
L-605 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
100 Hrs.
10 Hrs.
1000 Hrs.
500 Hrs.
1/2 Hr.

FIG. 161



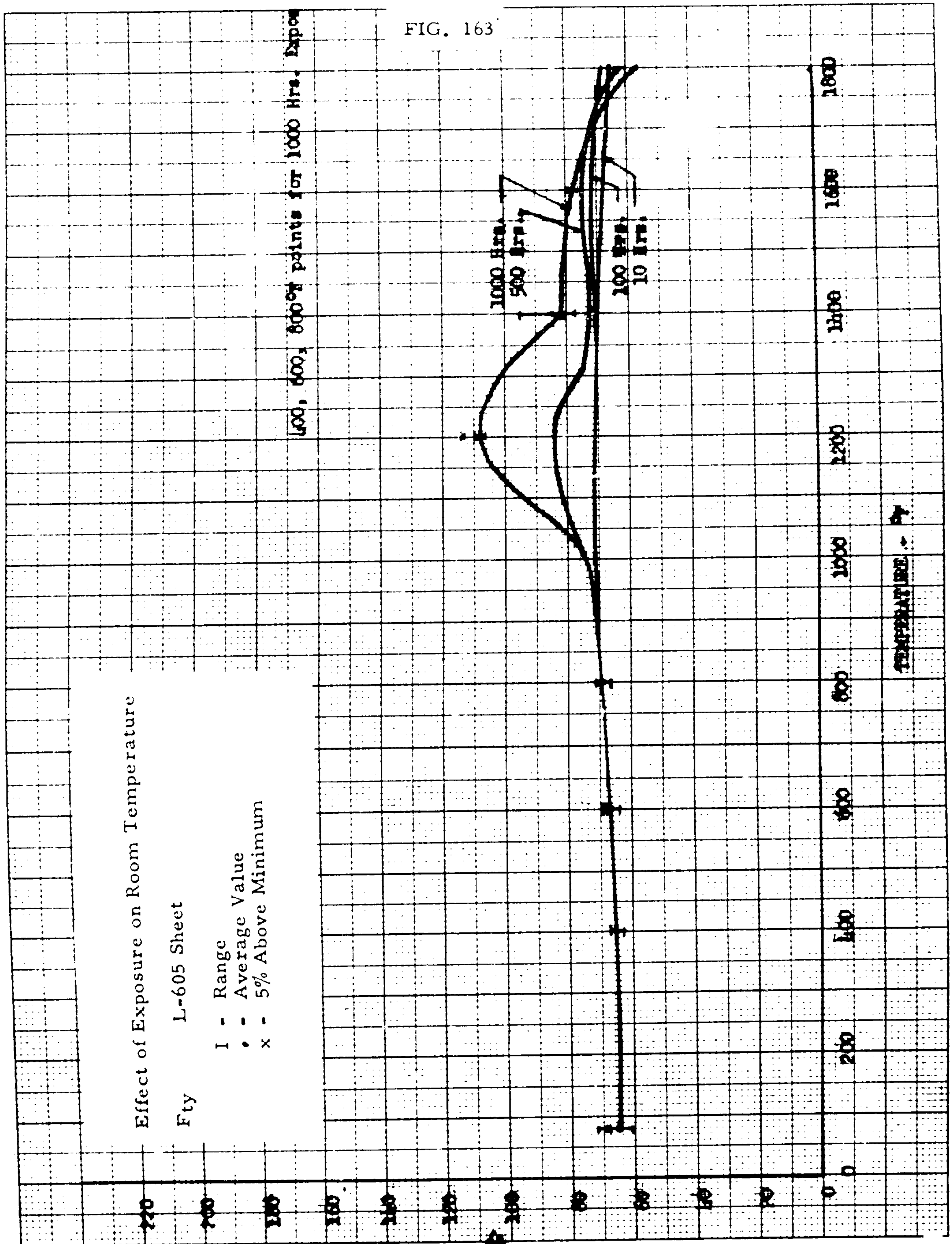
Effect of Exposure on Elevated Temperature F_{ty}
L - 605 Sheet
I - Range
. - Average Value
x - 5% Above Minimum
400, 600, 800°F points for 1000 hours Exposure
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
1/2 Hr.
F_{ty} - KSI
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE °F

FIG. 162



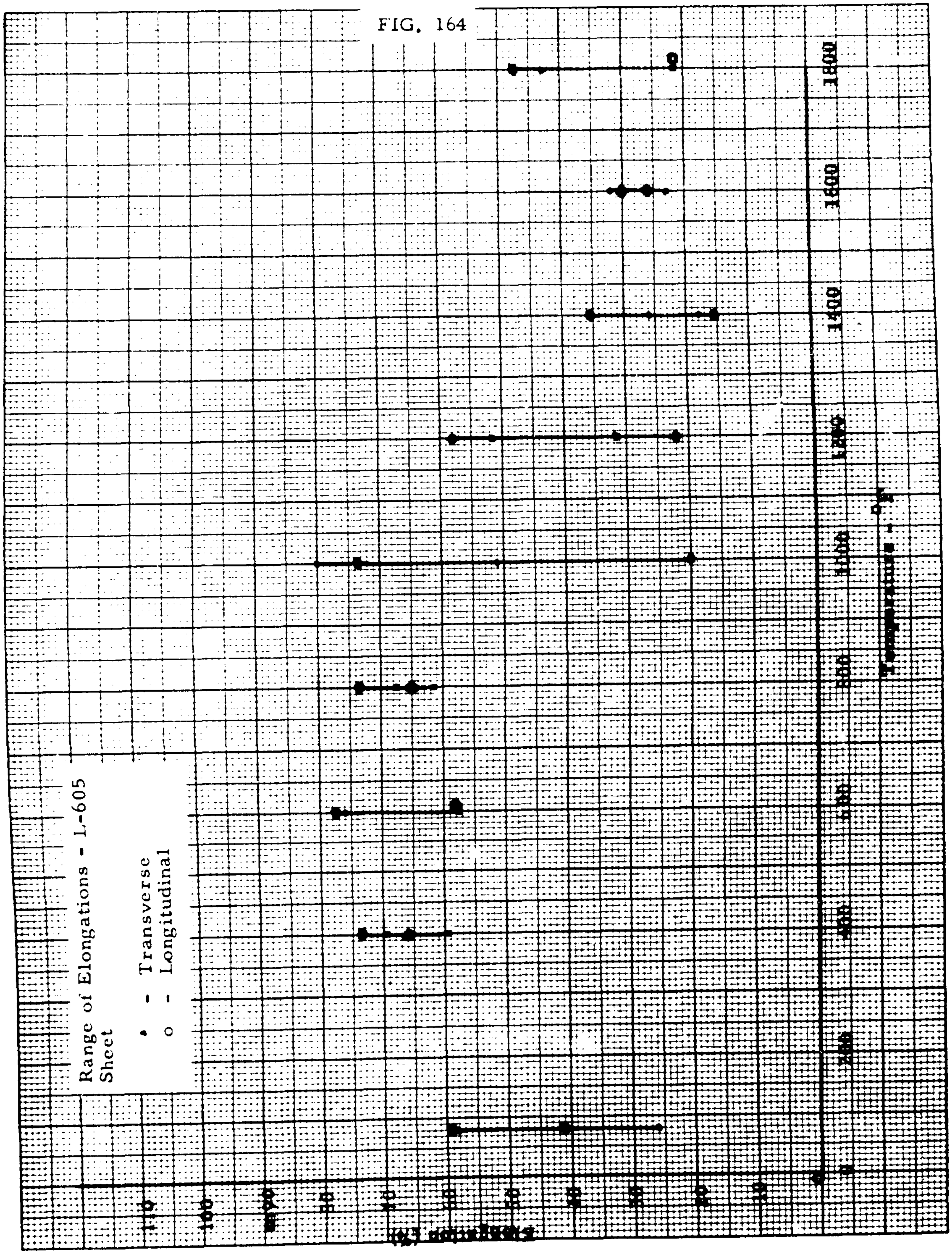
Effect of Exposure on Room Temperature
F tu L-605 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
400, 600, 800 & 1000°F points - all 1000 Hrs. Exposure
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
1600
1800

FIG. 163

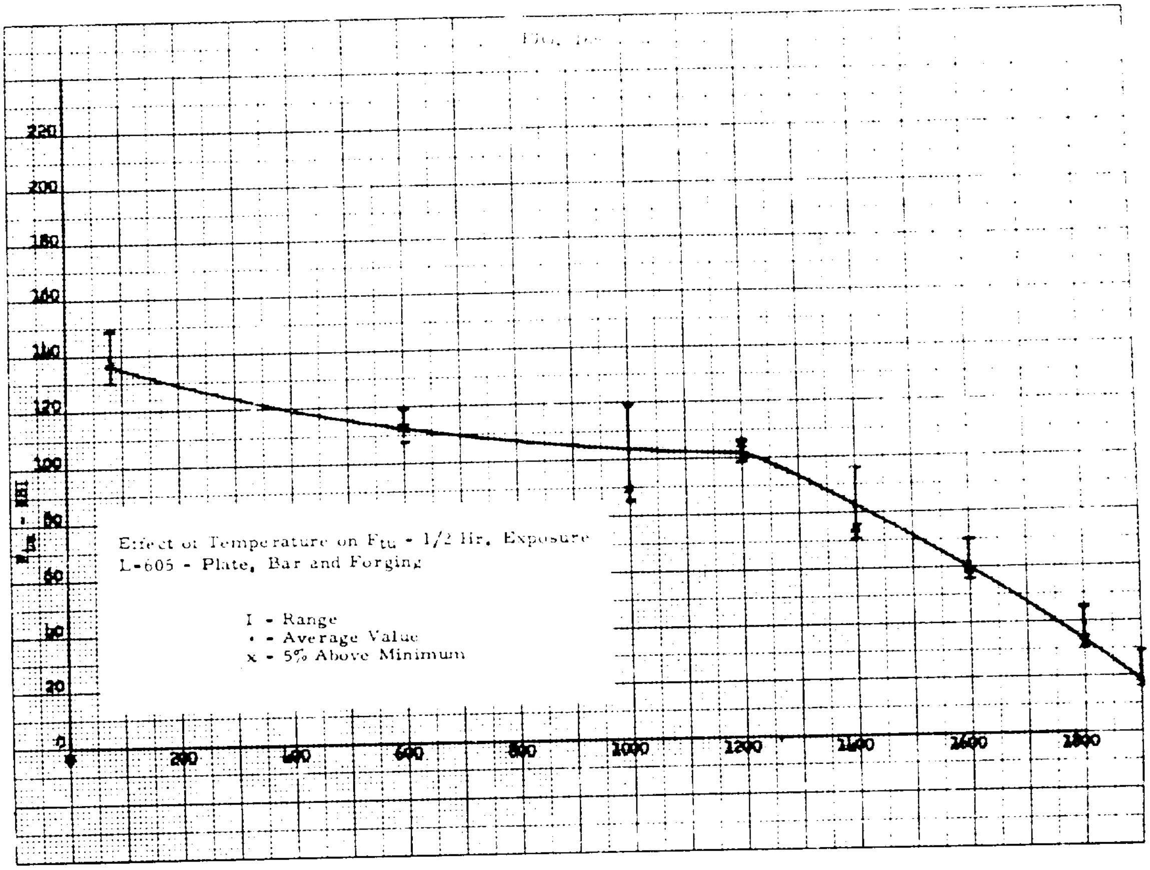


Effect of Exposure on Room Temperature
Fty
L-605 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
400, 600, 800°F points for 1000 Hrs. Expo
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
F - KSI
220
200
180
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE - °F

FIG. 164



Range of Elongations - L-605
Sheet
• - Transverse
o - Longitudinal
Temperature - °F
Elongation (%)
0
200
400
600
800
1000
1200
1400
1600
1800
10
20
30
40
50
60
70
80
90
100
110


Effect of Temperature on Ftu - 1/2 Hr. Exposure
L-605 - Plate, Bar and Forging
I - Range
• - Average Value
x - 5% Above Minimum
220
200
180
160
140
120
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800

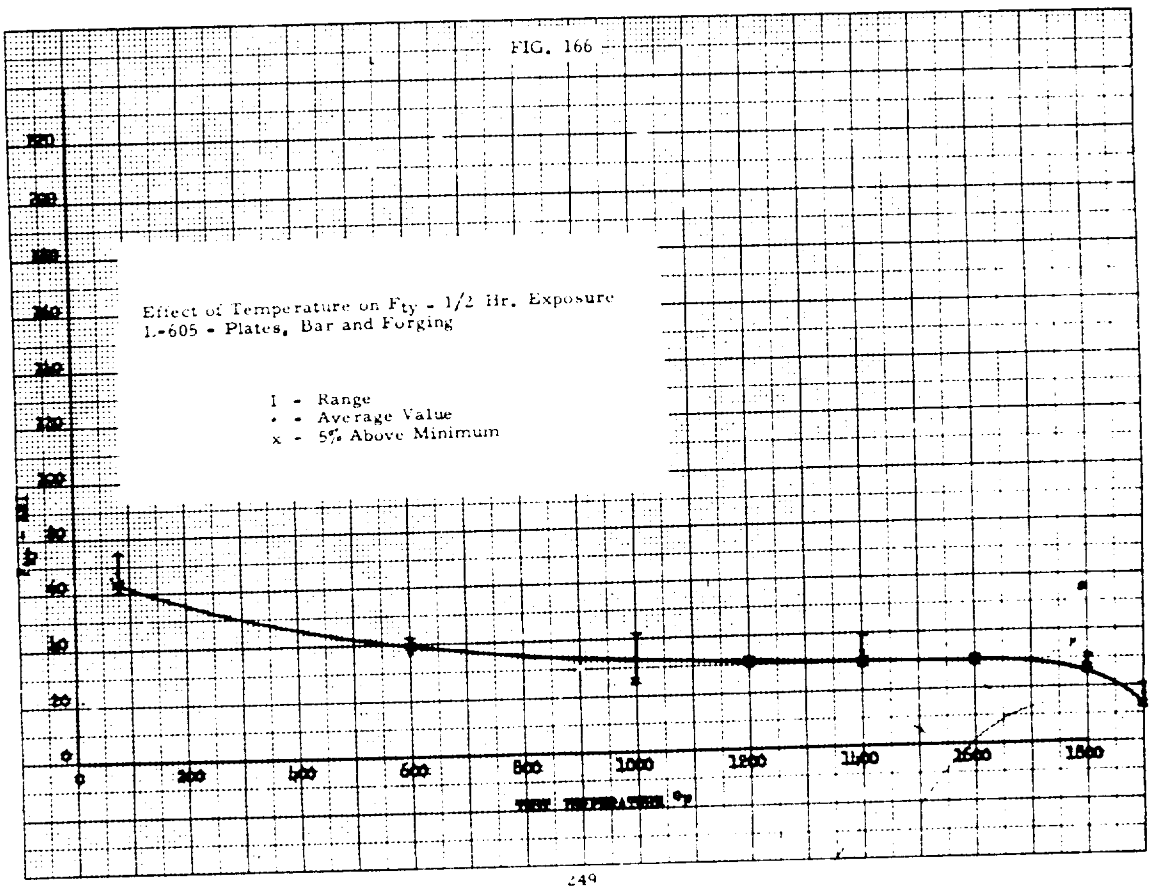
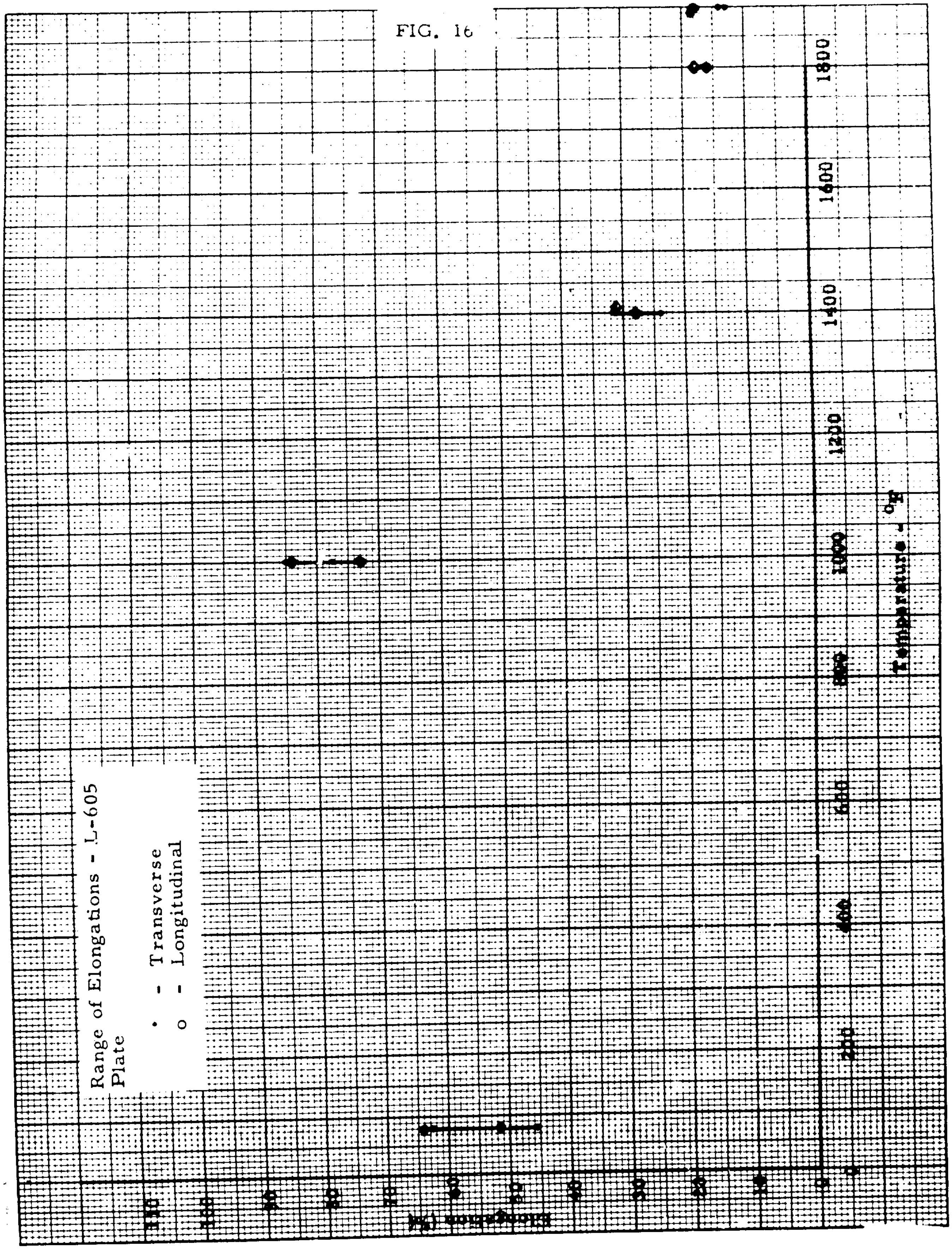


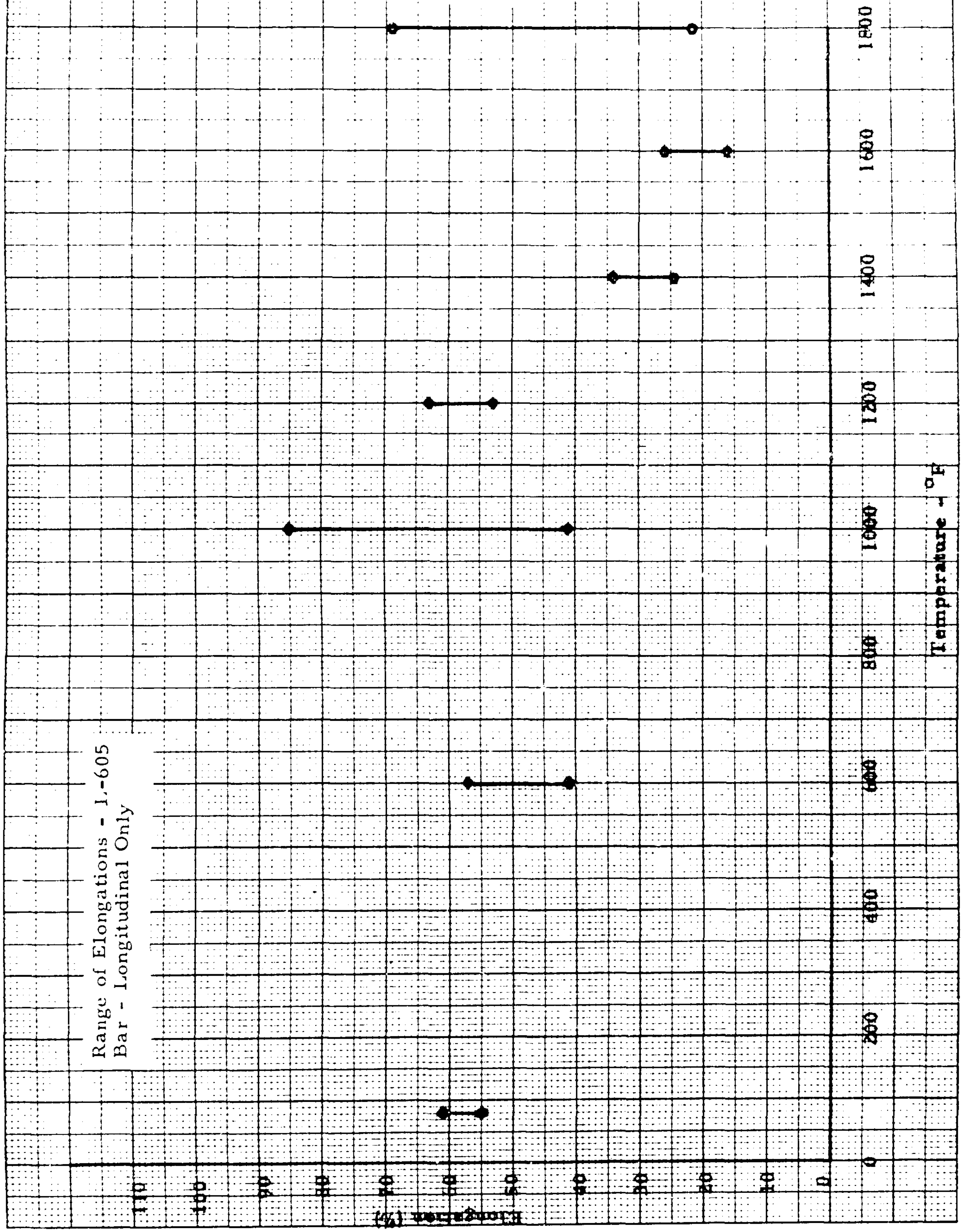
FIG. 166
Effect of Temperature on Fty - 1/2 Hr. Exposure
L-605 - Plates, Bar and Forging
I - Range
• - Average Value
x - 5% Above Minimum
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 16



Range of Elongations - L-605
Plate
• - Transverse
o - Longitudinal
Elongation (%)
Temperature - °F
0
200
400
600
800
1000
1200
1400
1600
1800
0
10
20
30
40
50
60
70
80
90
100
110

FIG. 168



Range of Elongations - L-605 Bar - Longitudinal Only

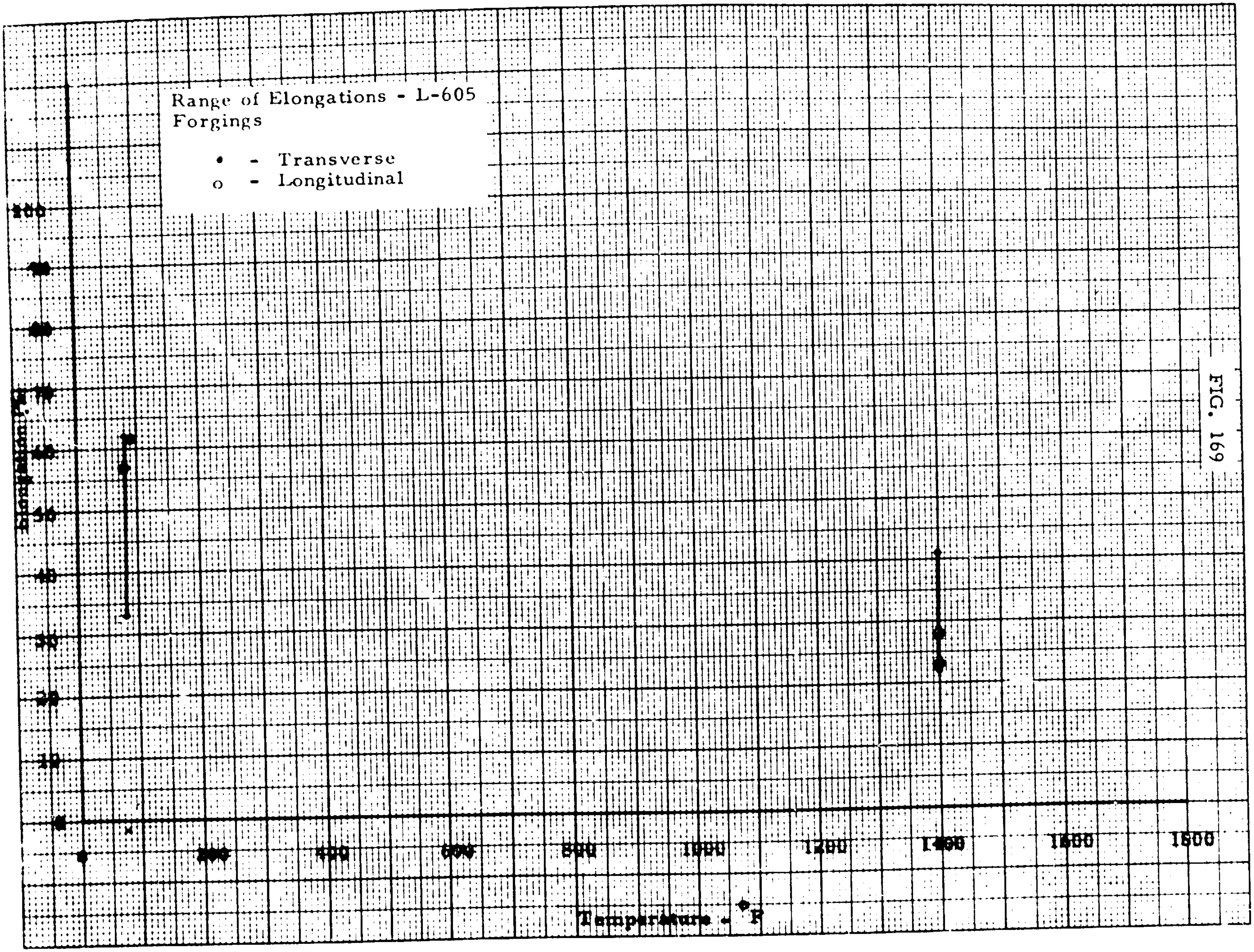

Range of Elongations - L-605
Forgings
• - Transverse
o - Longitudinal
Elongation, %
Temperature - °F
200
400
600
800
1000
1200
1400

FIG. 169

SECTION VII

SECTION 7.2.2 COMPRESSION

Figure 170 Effect of Temperature on Fcy
1/2 Hour Exposure - L605 Sheet (Longitudinal)

Figure 171 Effect of Temperature on Fcy
1/2 Hour Exposure - L605 Sheet (Transverse)

These two figures have been deleted, since they appear in Figure 172, Page 255.

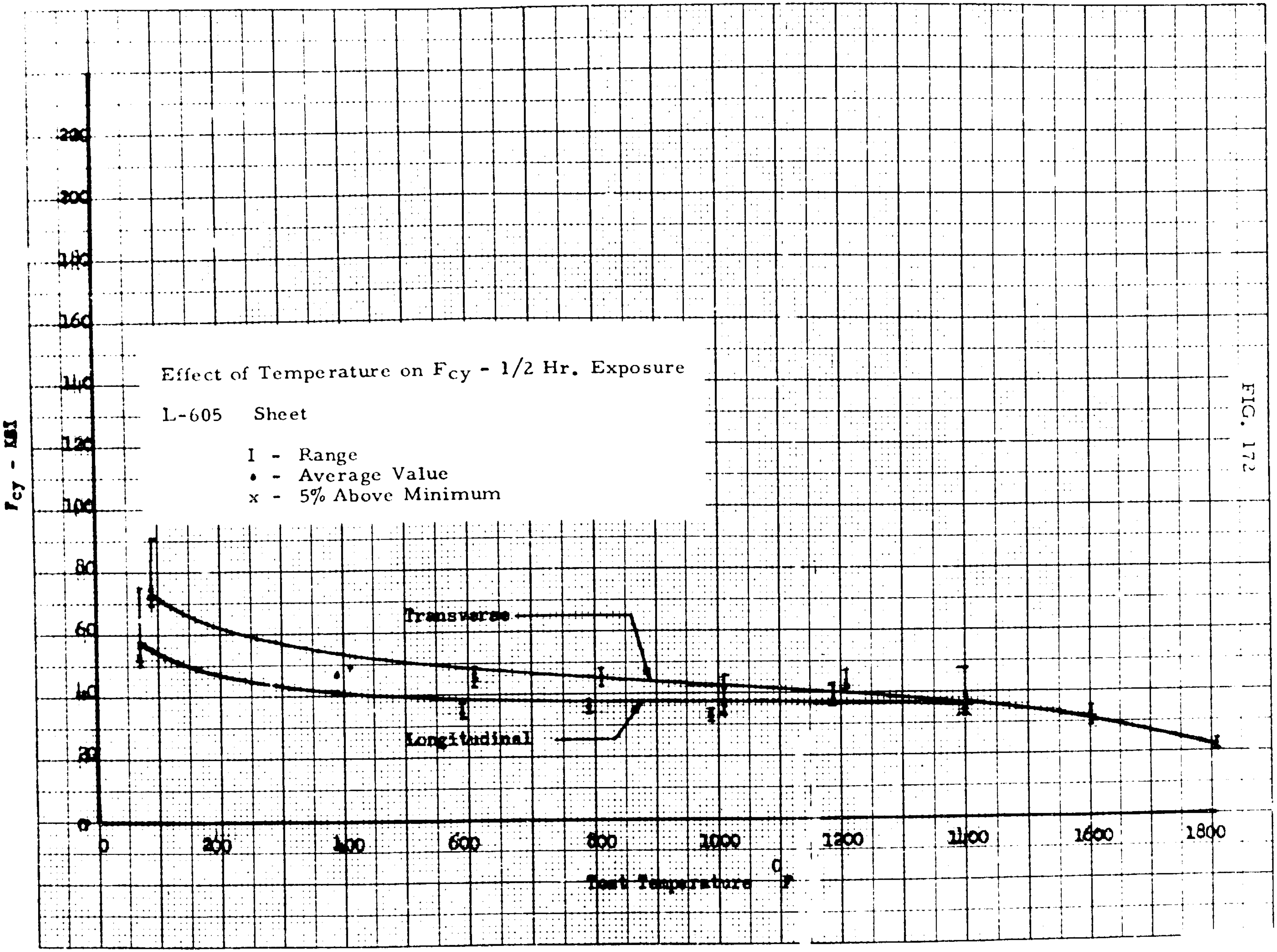

Effect of Temperature on F_{cy} - 1/2 Hr. Exposure
L-605 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
Transverse
Longitudinal
F_{cy} - KSI
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800
Test Temperature °F

FIG. 172

FIG. 173

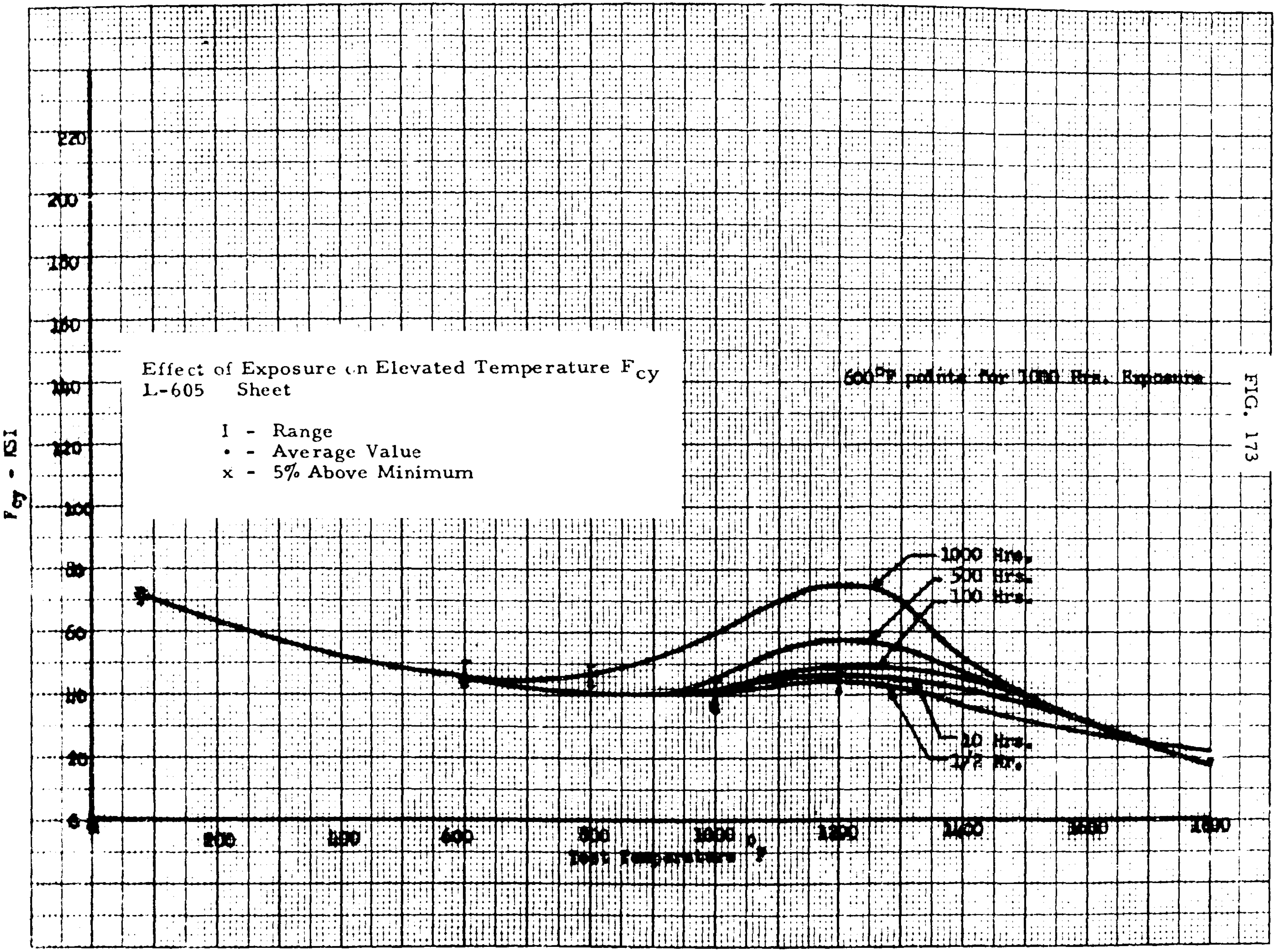

Effect of Exposure on Elevated Temperature F_{cy}
L-605 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
600°F points for 1000 Hrs. Exposure
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
1/2 Hr.
F_{cy} - KSI
Test Temperature °F
0
20
40
60
80
100
120
140
160
180
200
220
200
400
600
800
1000
1200
1400
1600
1800

FIG. 174

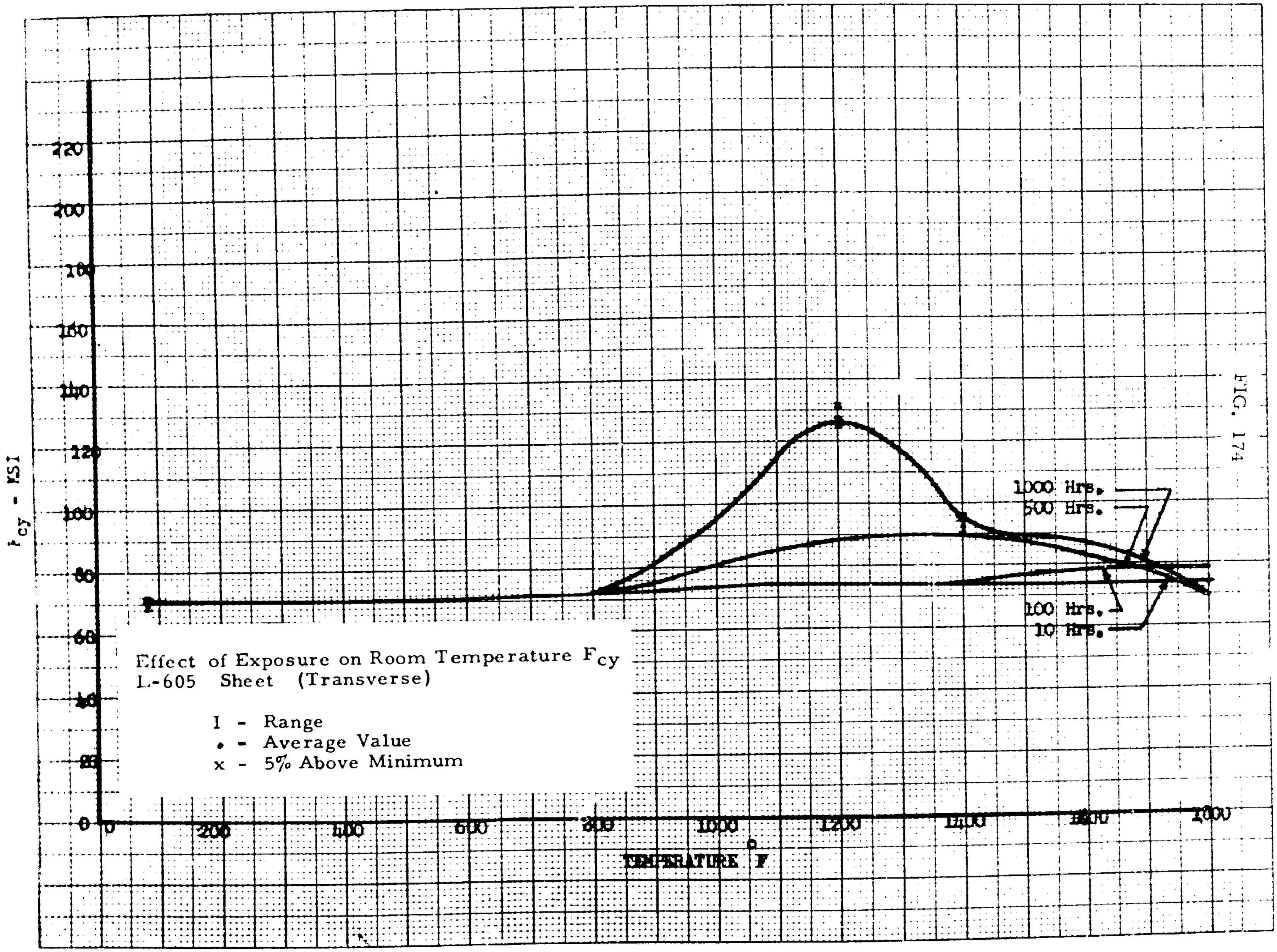
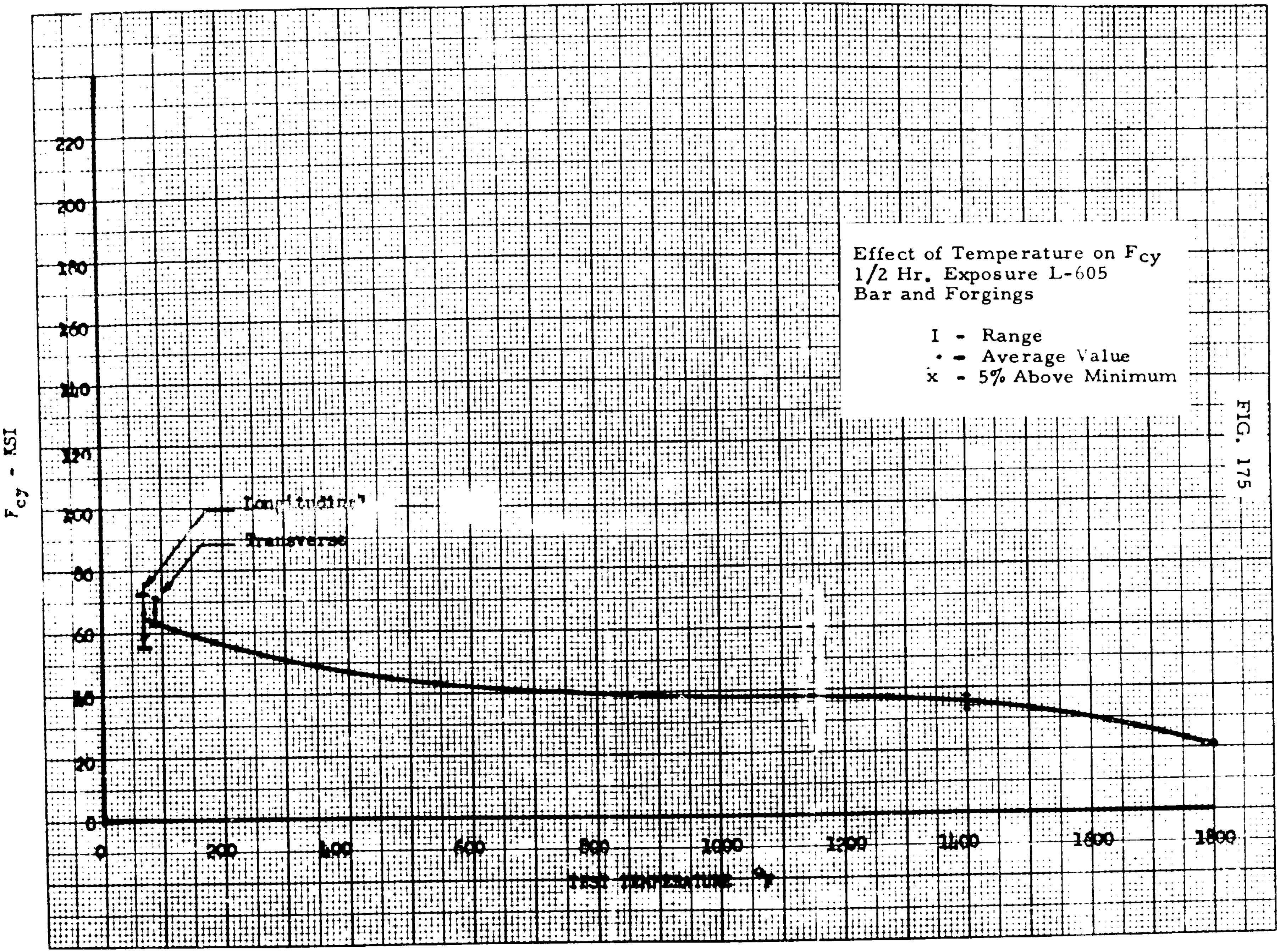
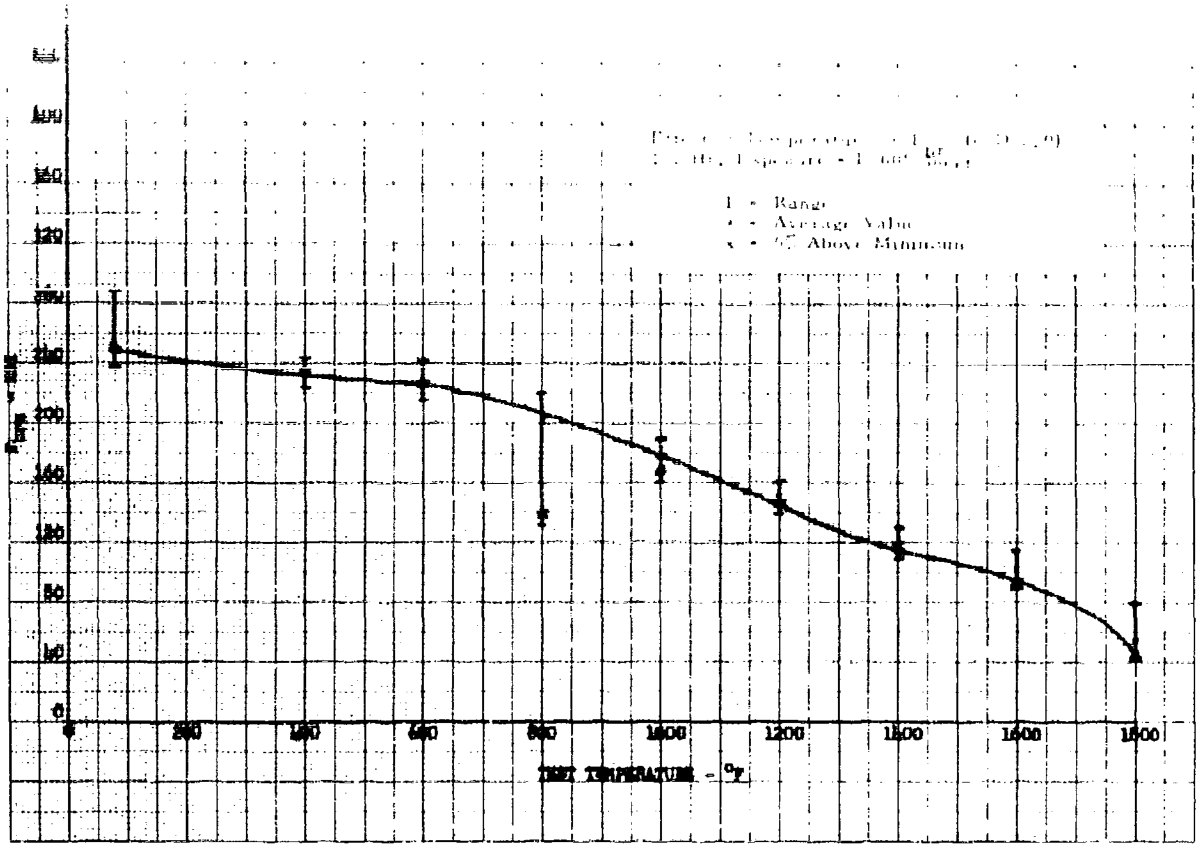

Effect of Exposure on Room Temperature F_{cy}
L-605 Sheet (Transverse)
I - Range
• - Average Value
x - 5% Above Minimum
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
F_{cy} - KSI
TEMPERATURE °F
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
2000

FIG. 175


Effect of Temperature on F_{cy}
1/2 Hr. Exposure L-605
Bar and Forgings
I - Range
• - Average Value
x - 5% Above Minimum
Transverse
F_{cy} - KSI
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800

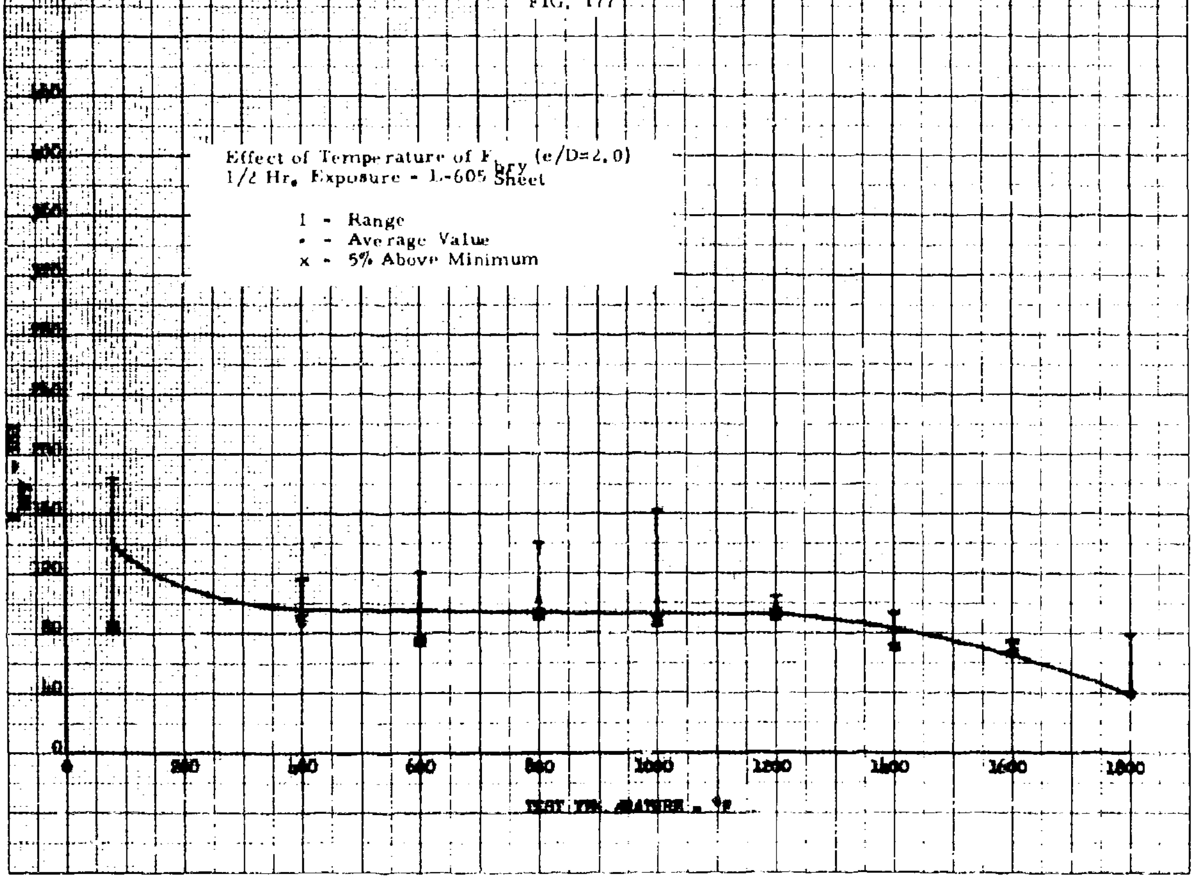
SECTION VII

SECTION 7.2.3 BEARING



I - Range
x - 5% Above Minimum
0
1200
1800

FIG. 177



Effect of Temperature of F_{bry} (e/D=2.0)
1/2 Hr. Exposure - L-605 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
0

FIG. 178

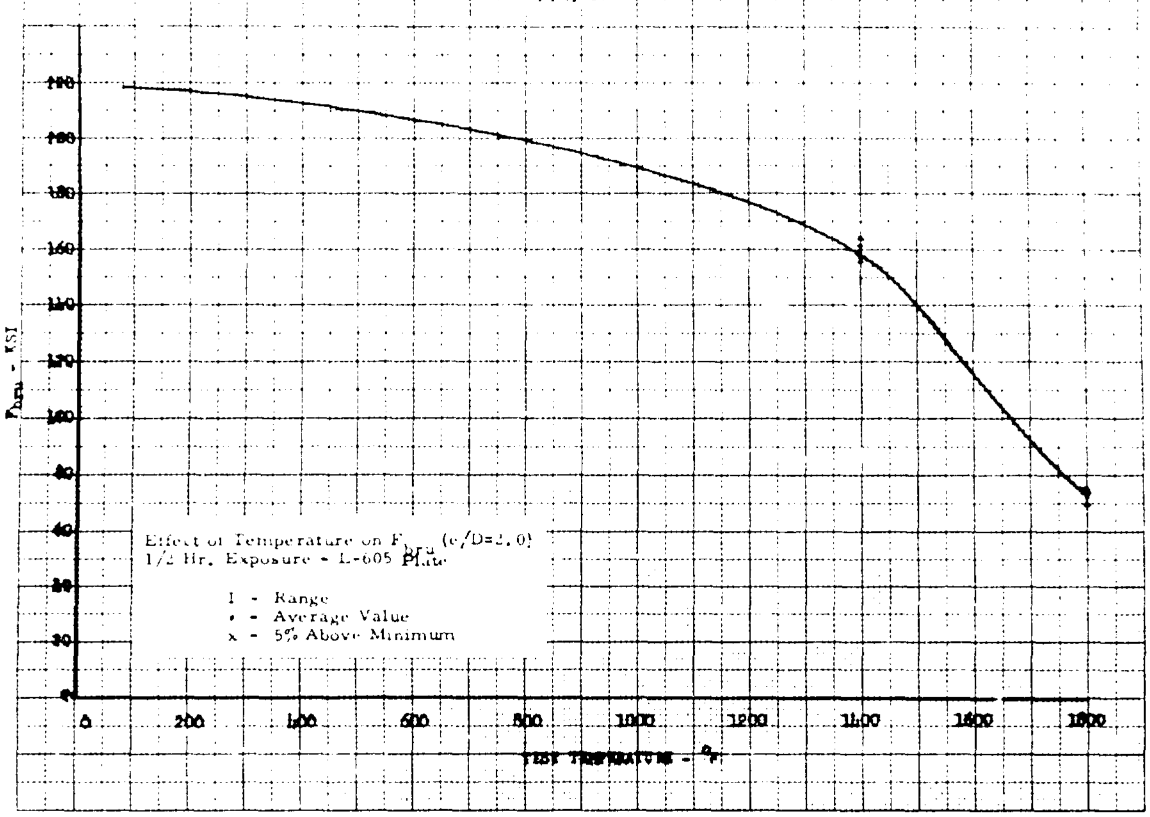


FIG. 179

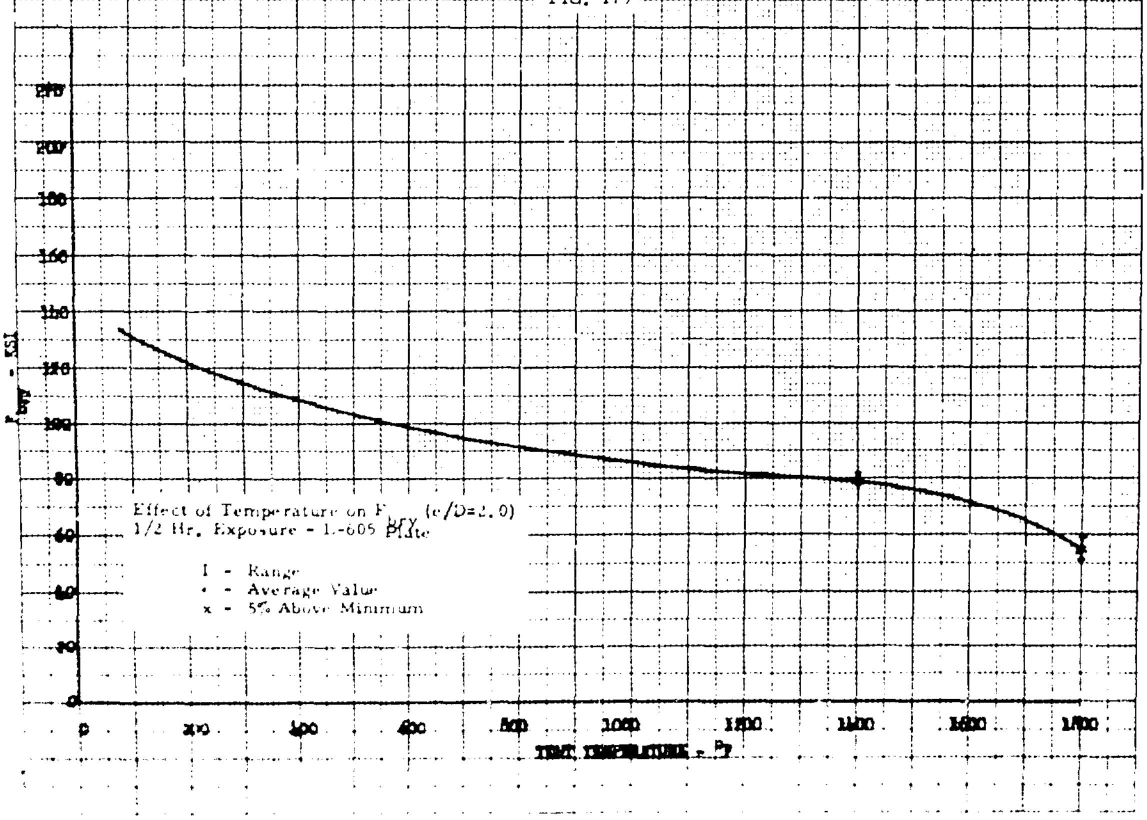
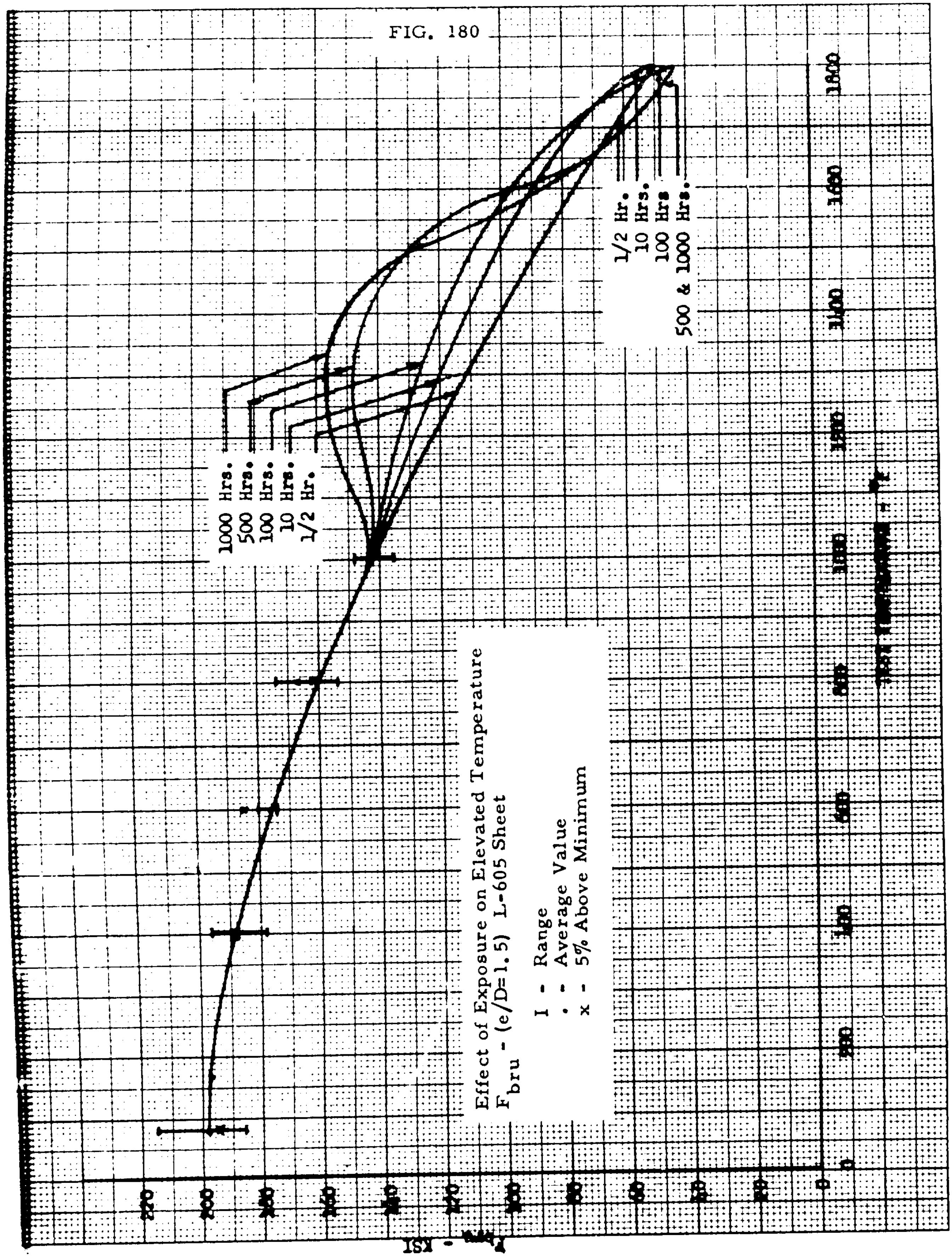
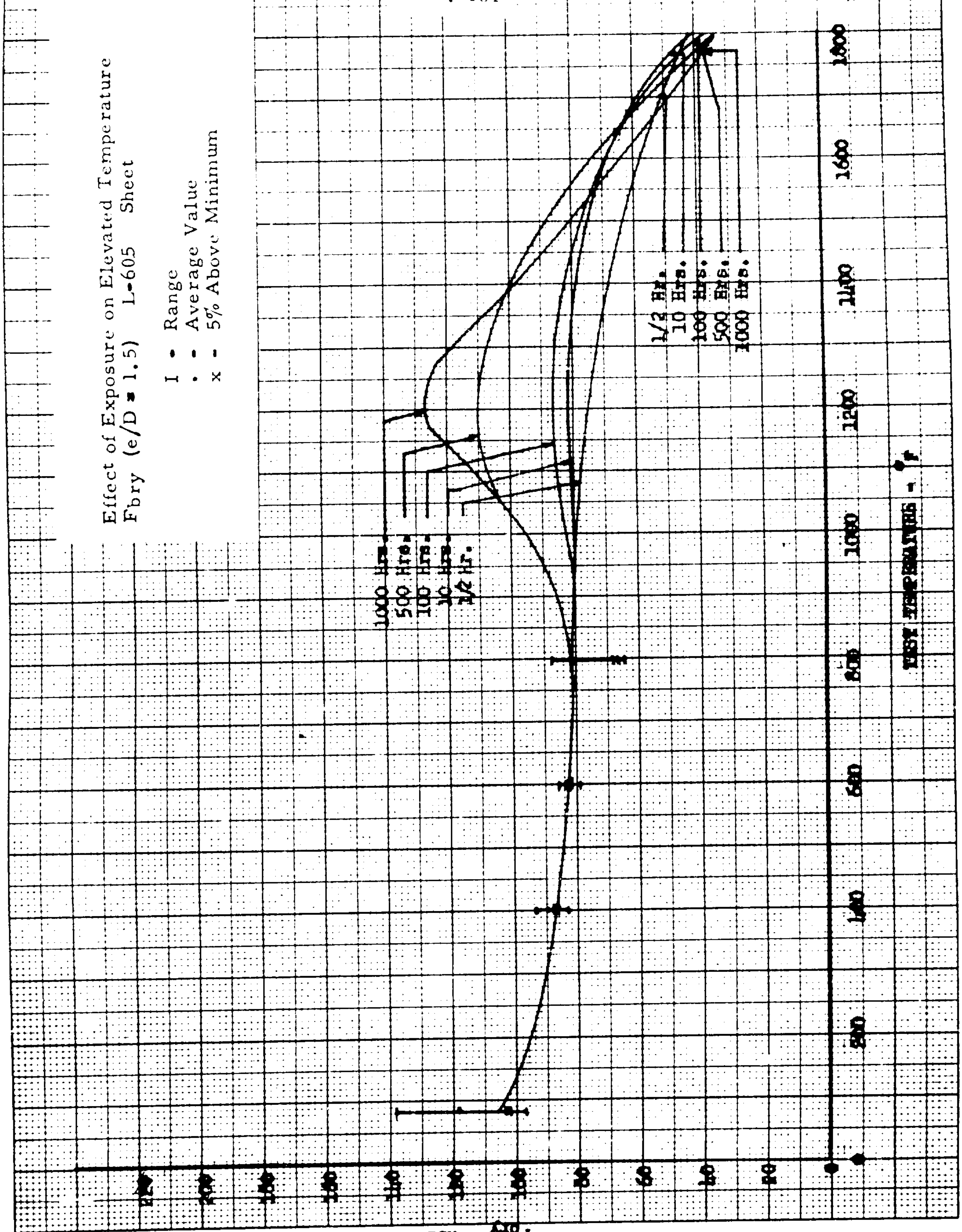


FIG. 180



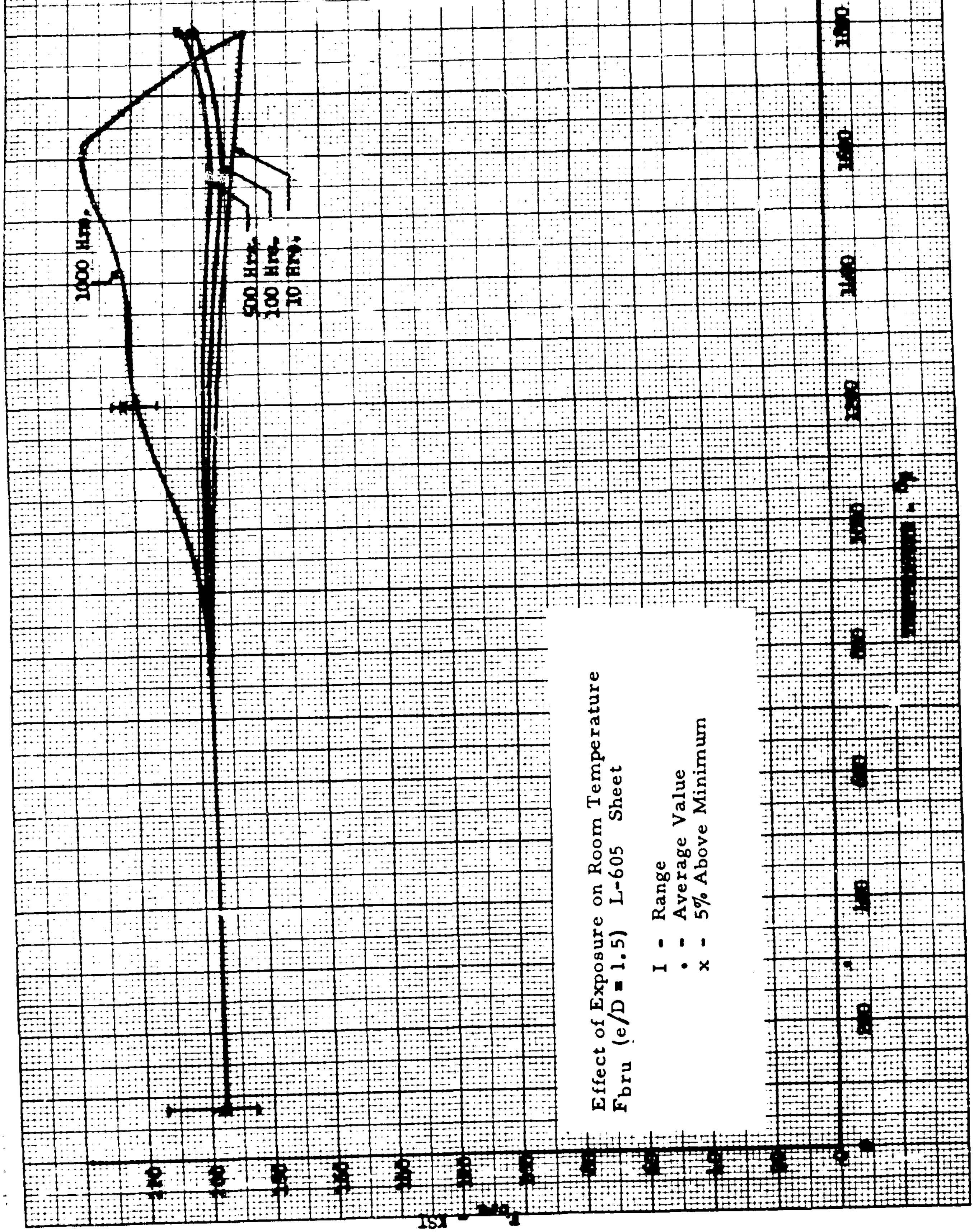
Effect of Exposure on Elevated Temperature
F_{bru} - (e/D=1.5) L-605 Sheet
I - Range
. - Average Value
x - 5% Above Minimum
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
1/2 Hr.
1/2 Hr.
10 Hrs.
100 Hrs
500 & 1000 Hrs.
F_{bru} - KSI
220
200
180
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 181



Effect of Exposure on Elevated Temperature
Fbry (e/D = 1.5) L-605 Sheet
I - Range
. - Average Value
x - 5% Above Minimum
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
1/2 Hr.
1/2 Hr.
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
20
40
60
80
100
120
140
160
180
200
220
200
400
600
800
1000
1200
1400
1600
1800
Fbry - KSI
TEST TEMPERATURE - °F

FIG. 182



Effect of Exposure on Room Temperature
F_{bru} (e/D = 1.5) L-605 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
KSI

FIG. 183

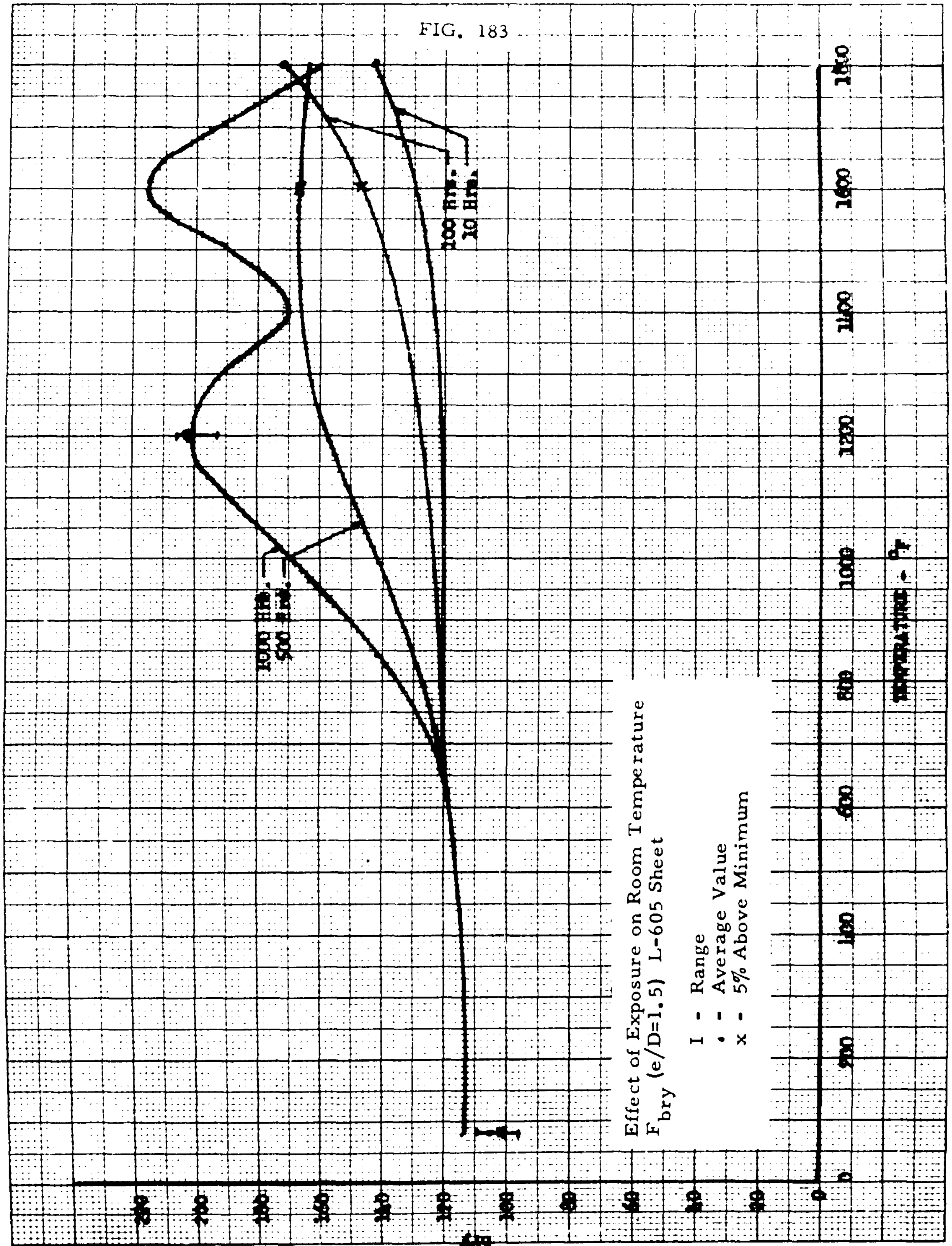

Effect of Exposure on Room Temperature
F_{bry} (e/D=1.5) L-605 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
F_{bry} - KSI
TEMPERATURE - °F
0
200
400
600
800
1000
1200
1400
1600
1800
20
40
60
80
100
120
140
160
180
200
220

FIG. 184

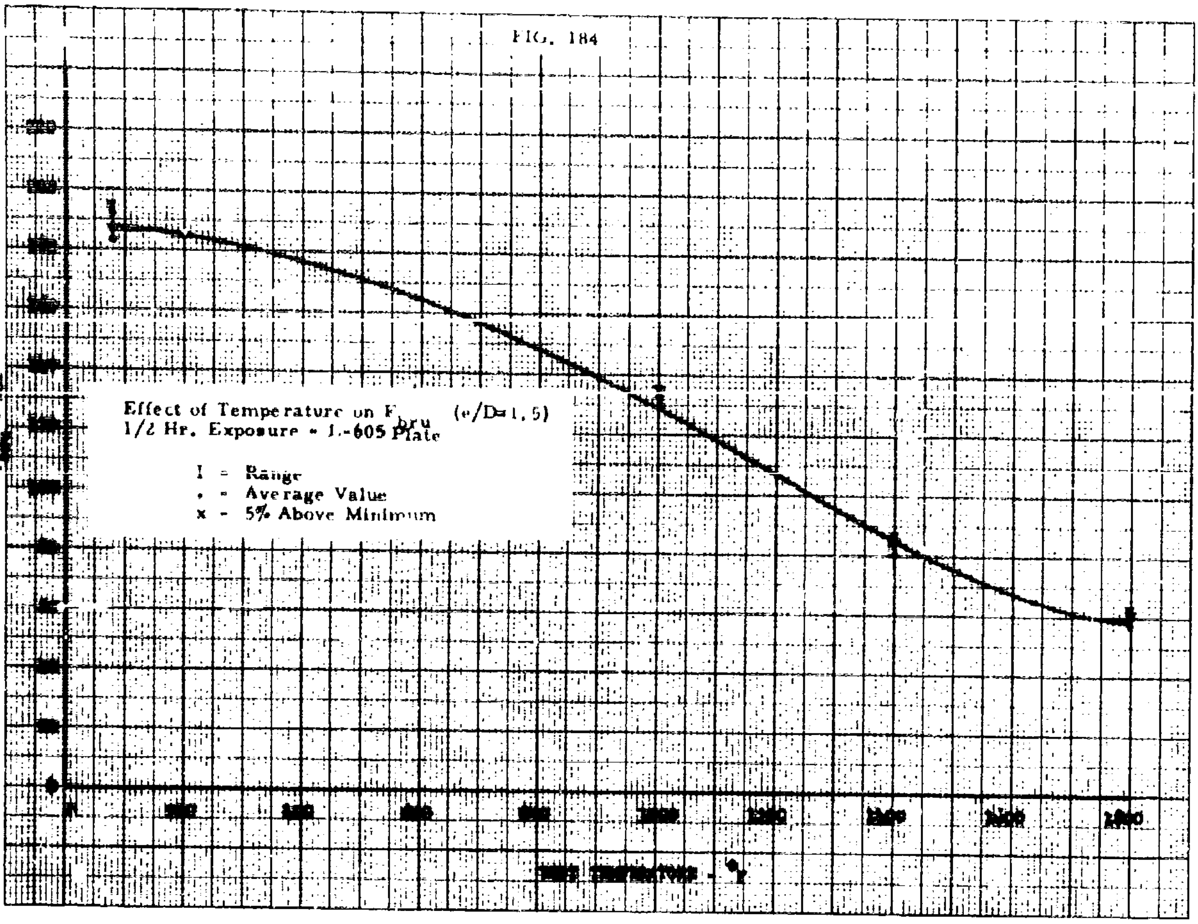
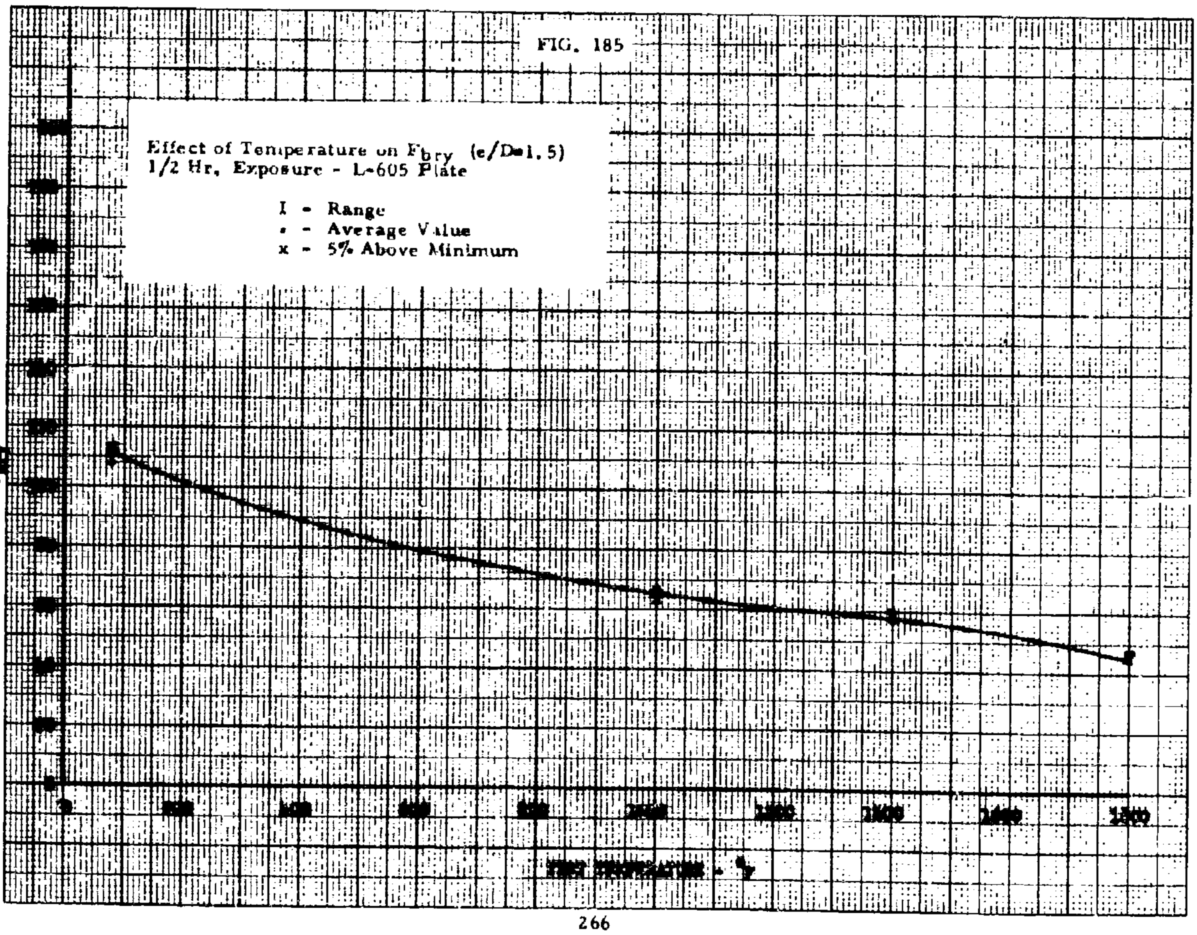


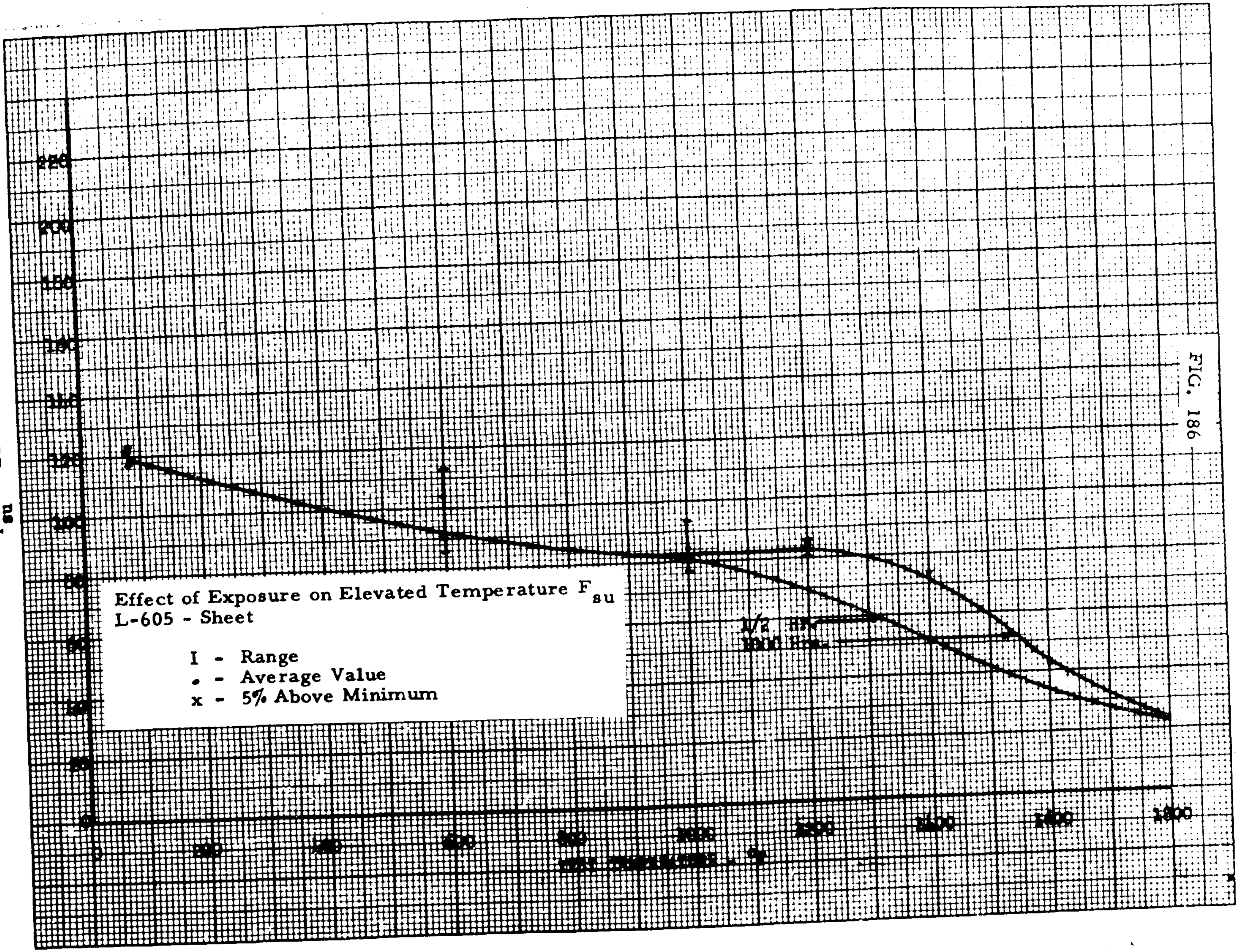
FIG. 185



SECTION VII

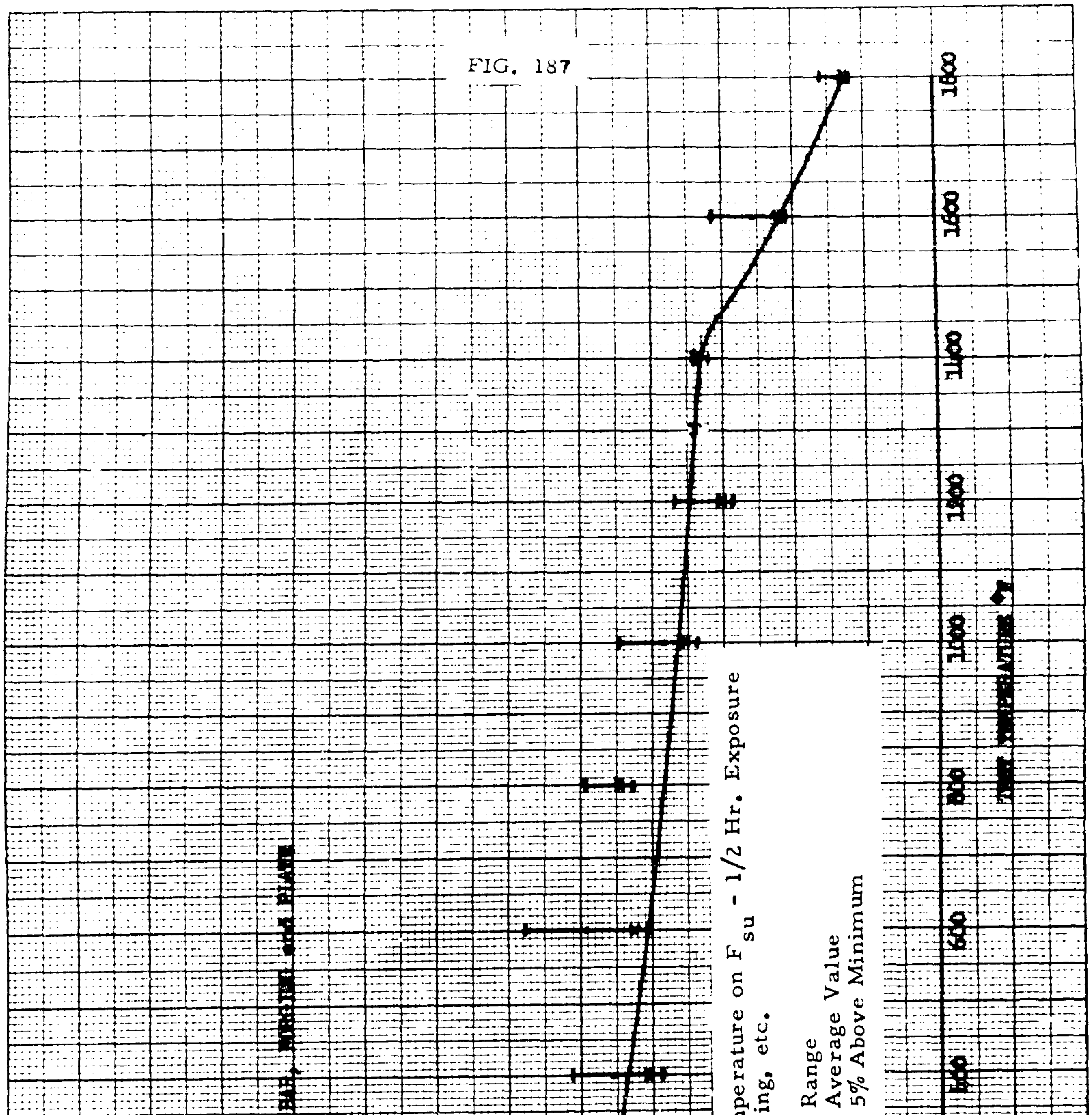
SECTION 7.2.4 SHEAR

FIG. 186



Effect of Exposure on Elevated Temperature F_{su}
L-605 - Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1/2 Hr.
F_{su} - KSI

FIG. 187

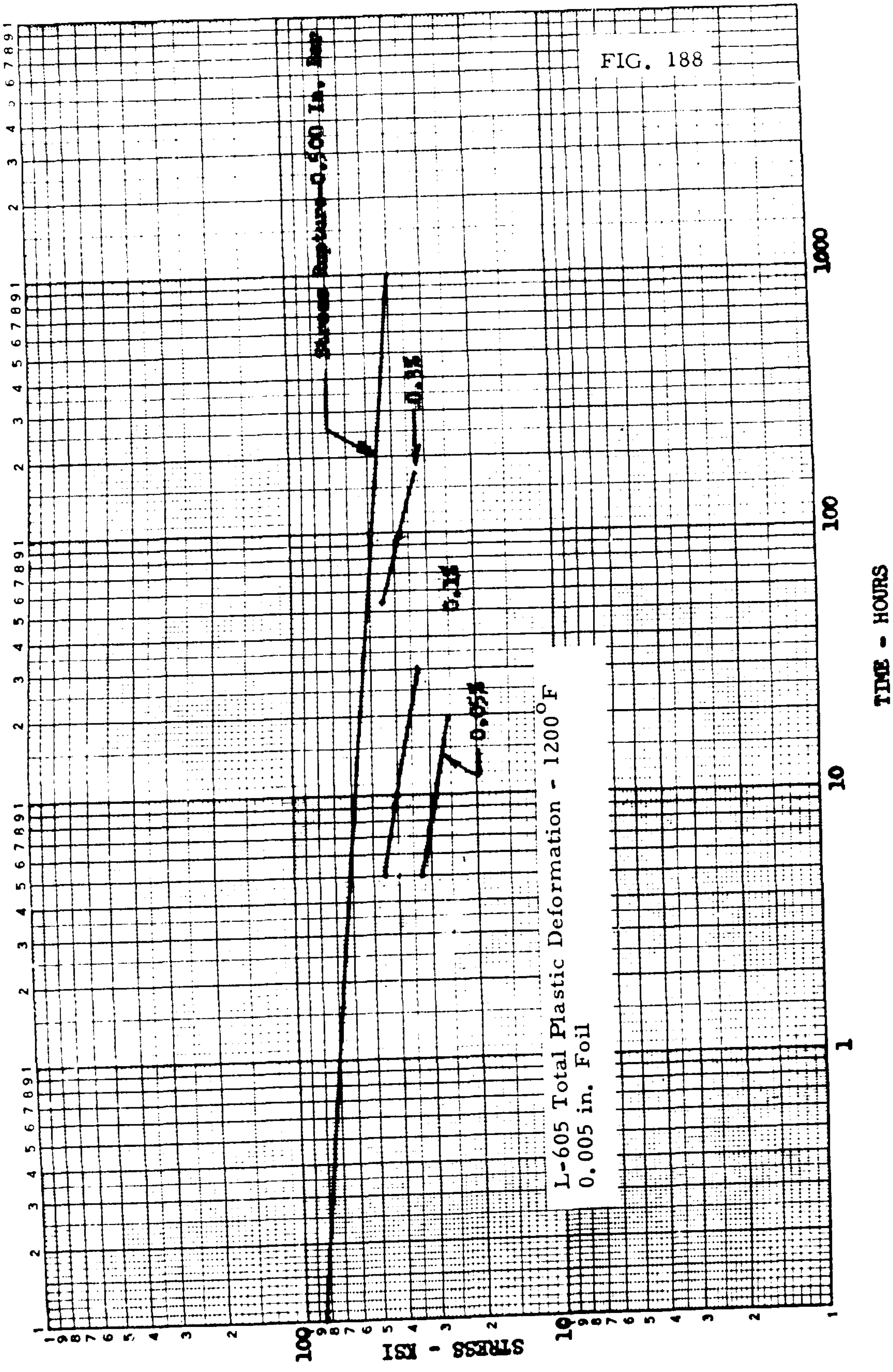

Effect of Temperature on F_{su} - 1/2 Hr. Exposure
L-605 - Forging, etc.
I - Range
. - Average Value
x - 5% Above Minimum
0
200
400
600
800
1000
1200
1400
1600
1800

SECTION VII

SECTION 7.2.5 CREEP

TIME - HOURS

FIG. 188



L-605 Total Plastic Deformation - 1200°F
0.005 in. Foil
Stress Rupture 0.500 In. Bar
0.5%
0.1%
0.05%
TIME - HOURS
STRESS - KSI
1
10
100
1000

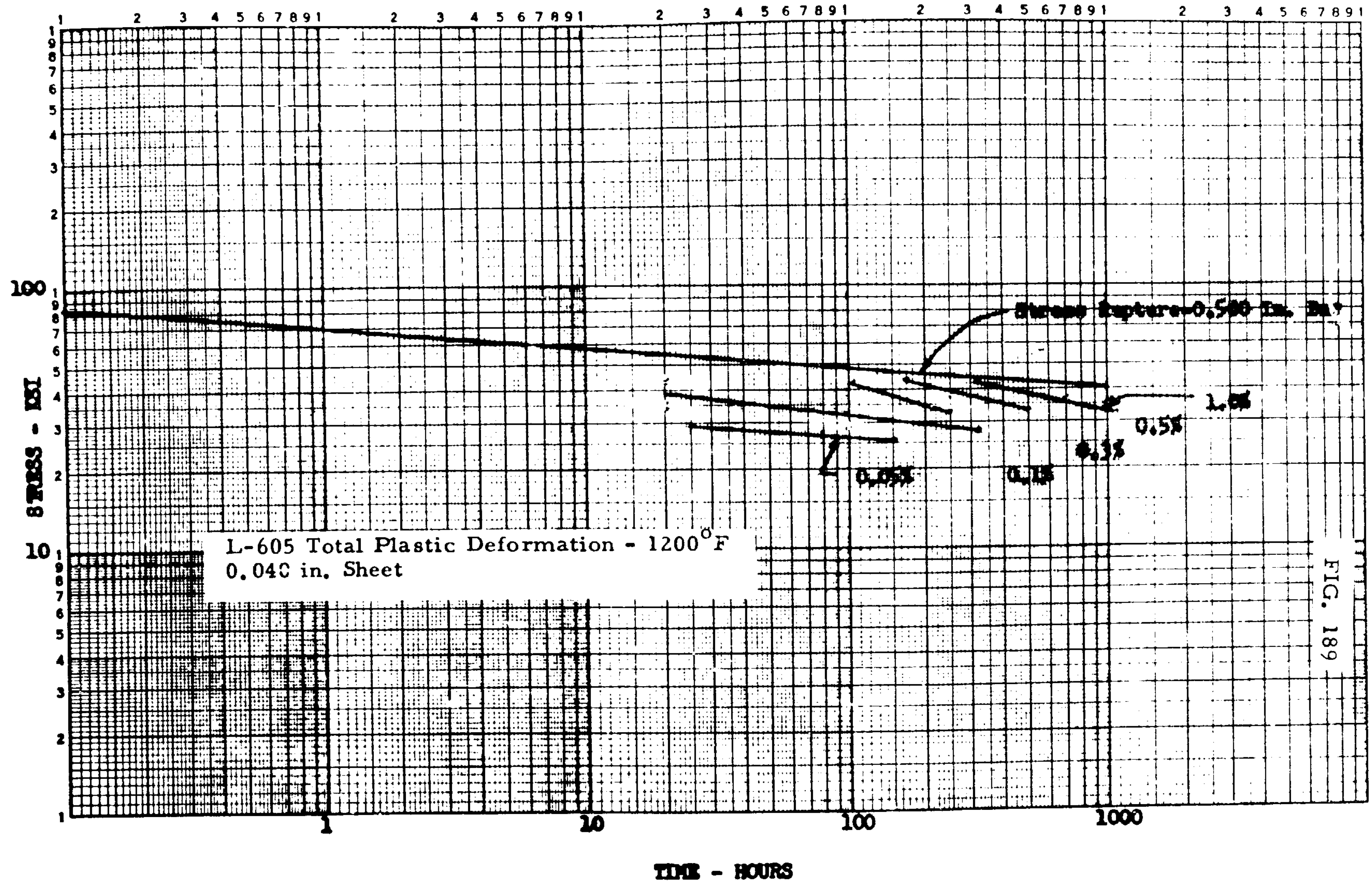
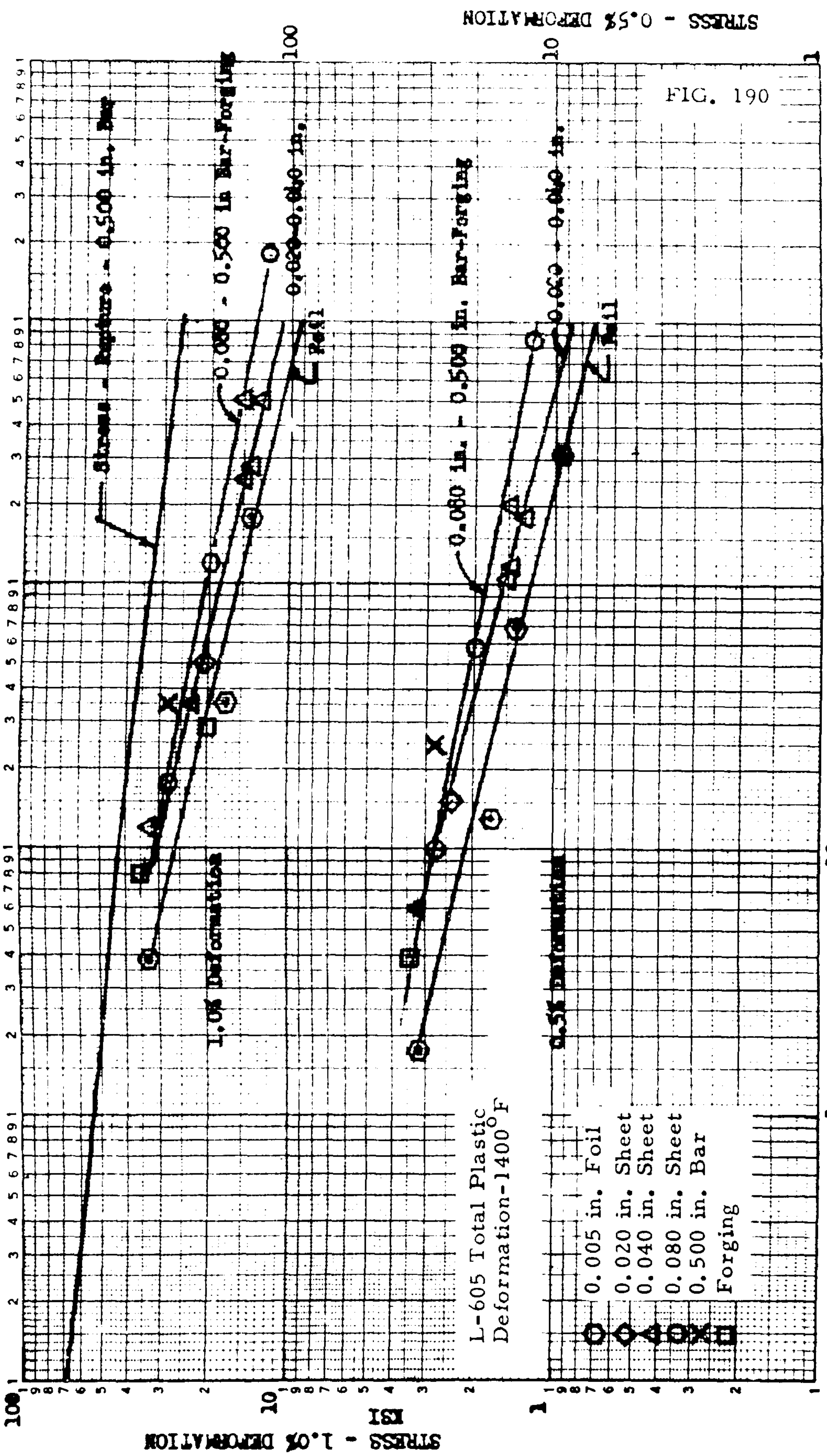


FIG. 189

L-605 Total Plastic Deformation - 1200°F
0.040 in. Sheet



STRESS - 0.5% DEFORMATION
STRESS - 1.0% DEFORMATION
KSI
TIME - HOURS
Stress - Rupture - 0.500 in. Bar
0.080 - 0.500 in Bar-Forging
0.020-0.040 in.
Foil
1.0% Deformation
0.080 in. - 0.500 in. Bar-Forging
0.020 - 0.040 in.
Foil
0.5% Deformation
L-605 Total Plastic
Deformation-1400°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging

FIG. 190

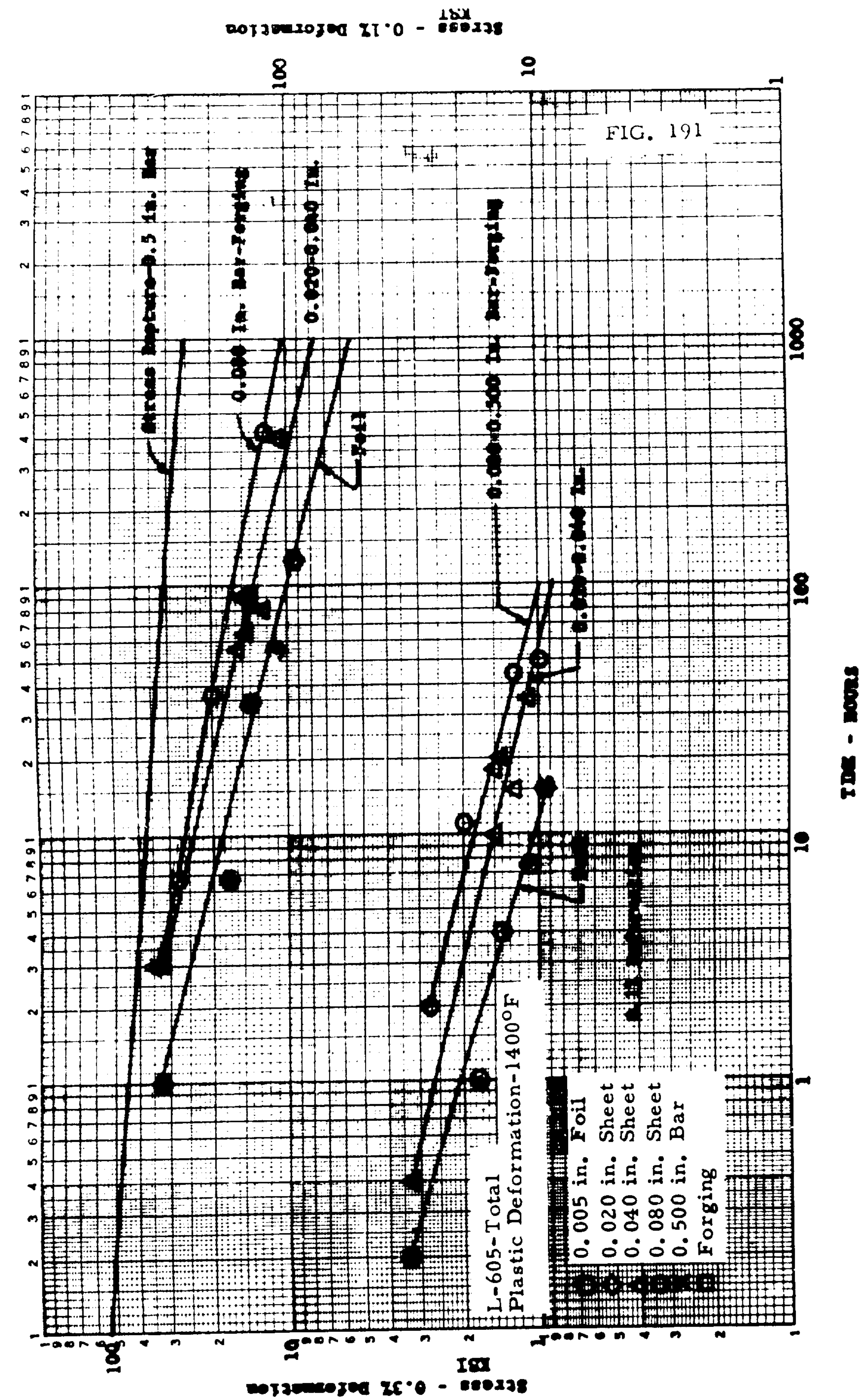


FIG. 191
Stress - 0.1% Deformation
KSI
Stress - 0.3% Deformation
KSI
TIME - HOURS
L-605-Total
Plastic Deformation-1400°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
Foil

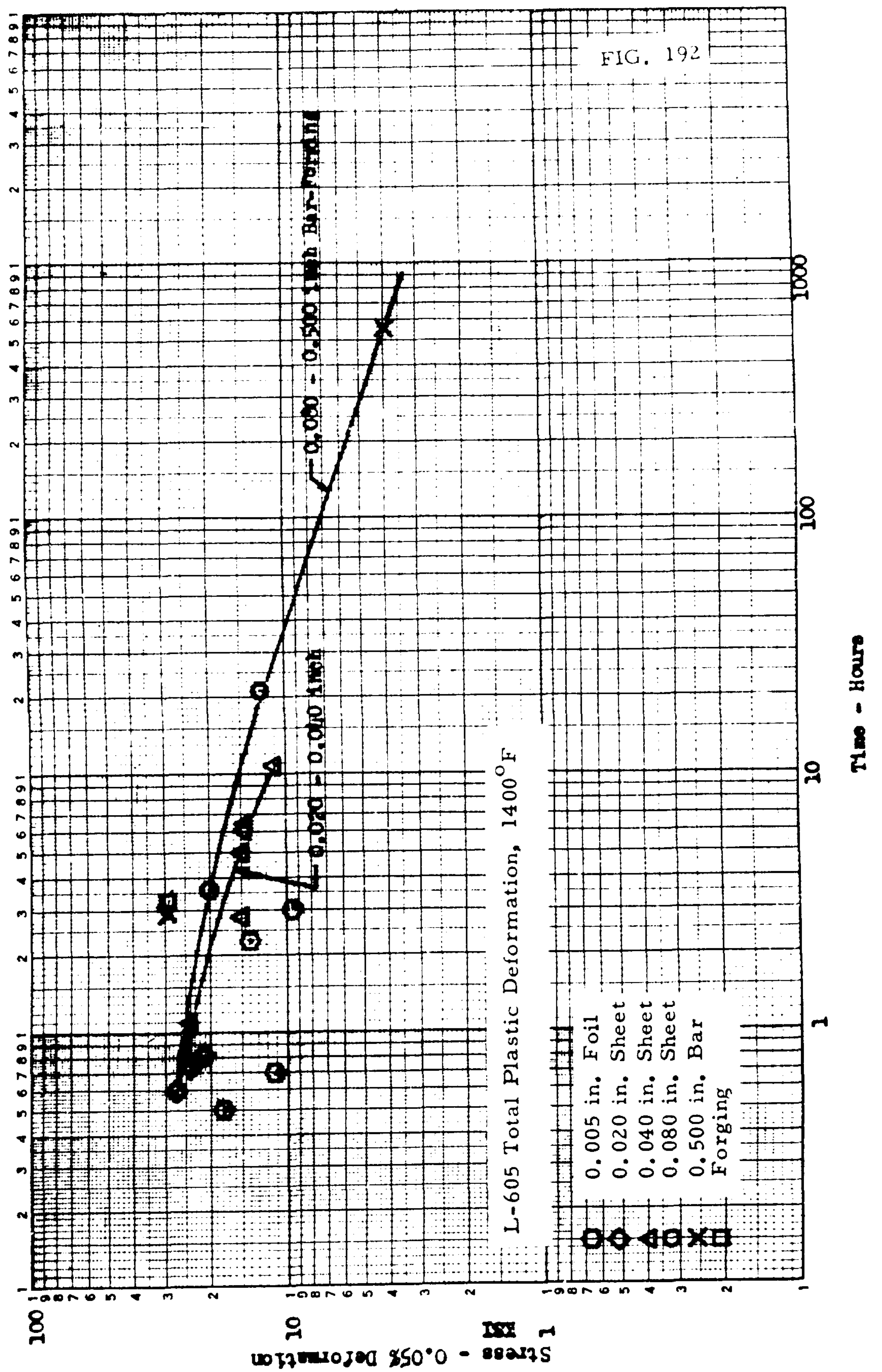


FIG. 192
L-605 Total Plastic Deformation, 1400°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar Forging
0.080 - 0.500 inch Bar-Forging
0.020 - 0.040 inch
Time - Hours
Stress - 0.05% Deformation
KSI

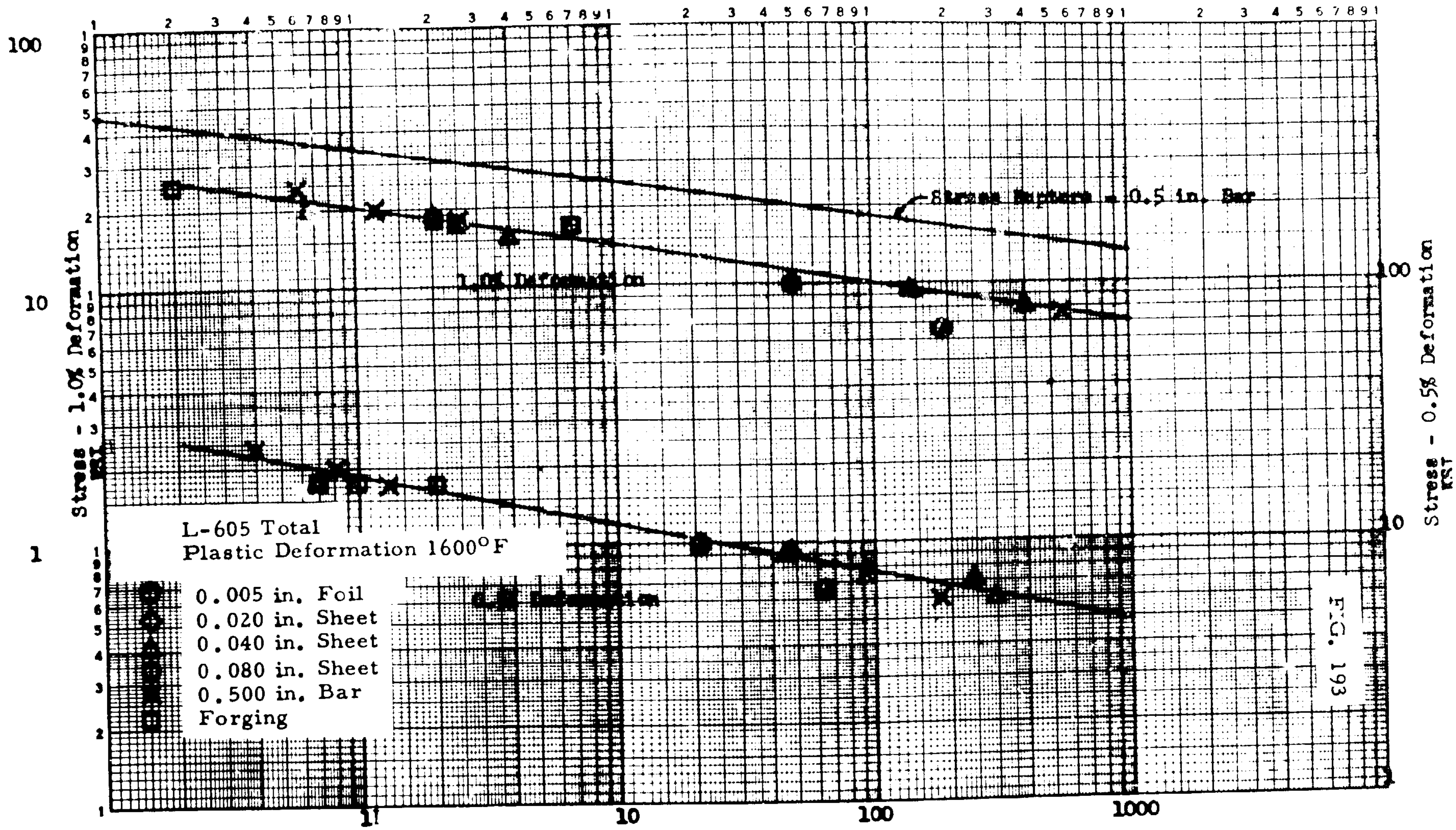


FIG. 193
L-605 Total
Plastic Deformation 1600°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
Stress Rupture - 0.5 in. Bar
1.0% Deformation
0.5% Deformation
Stress - 1.0% Deformation KSI
Stress - 0.5% Deformation KSI
100
10
1
1000

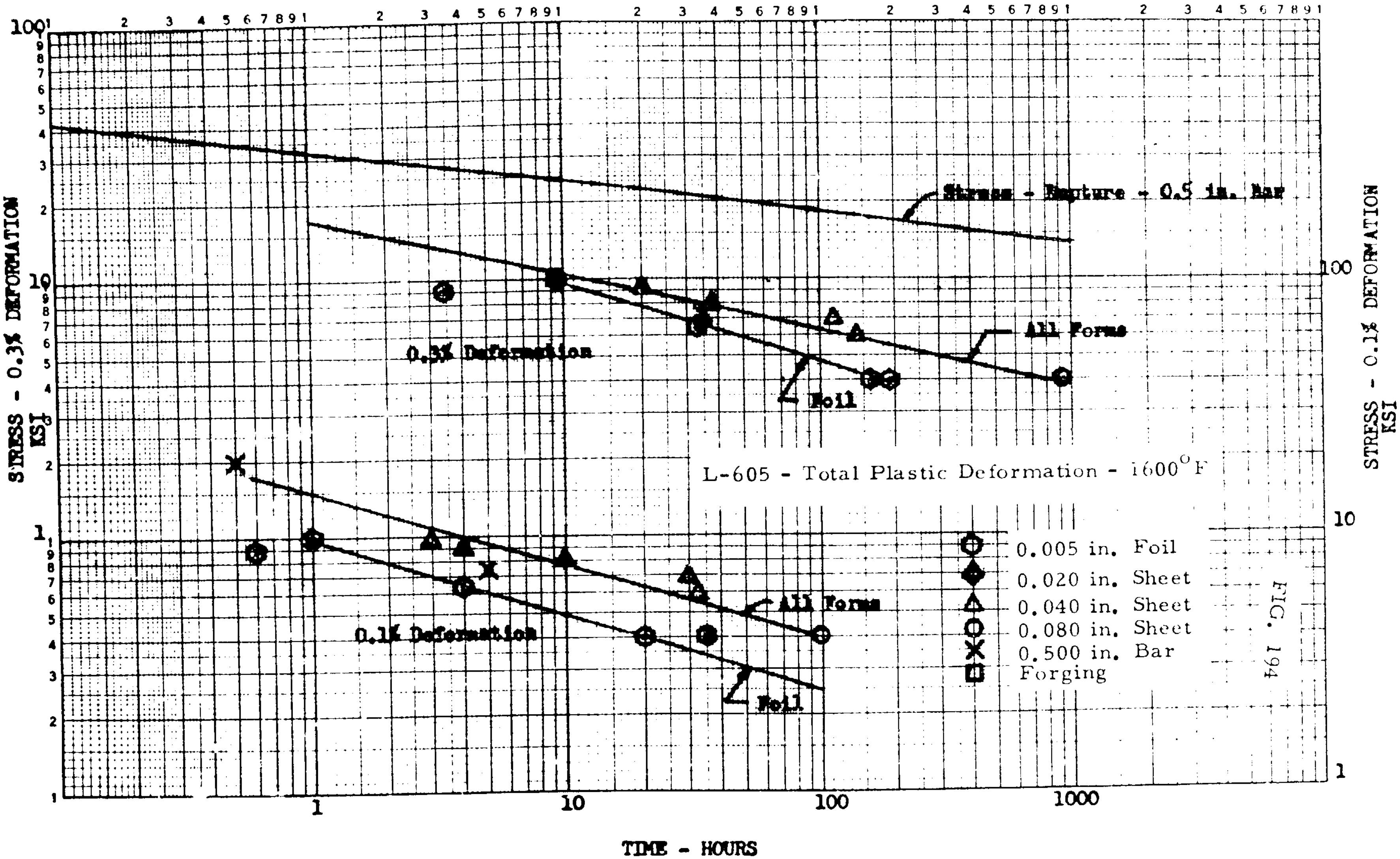
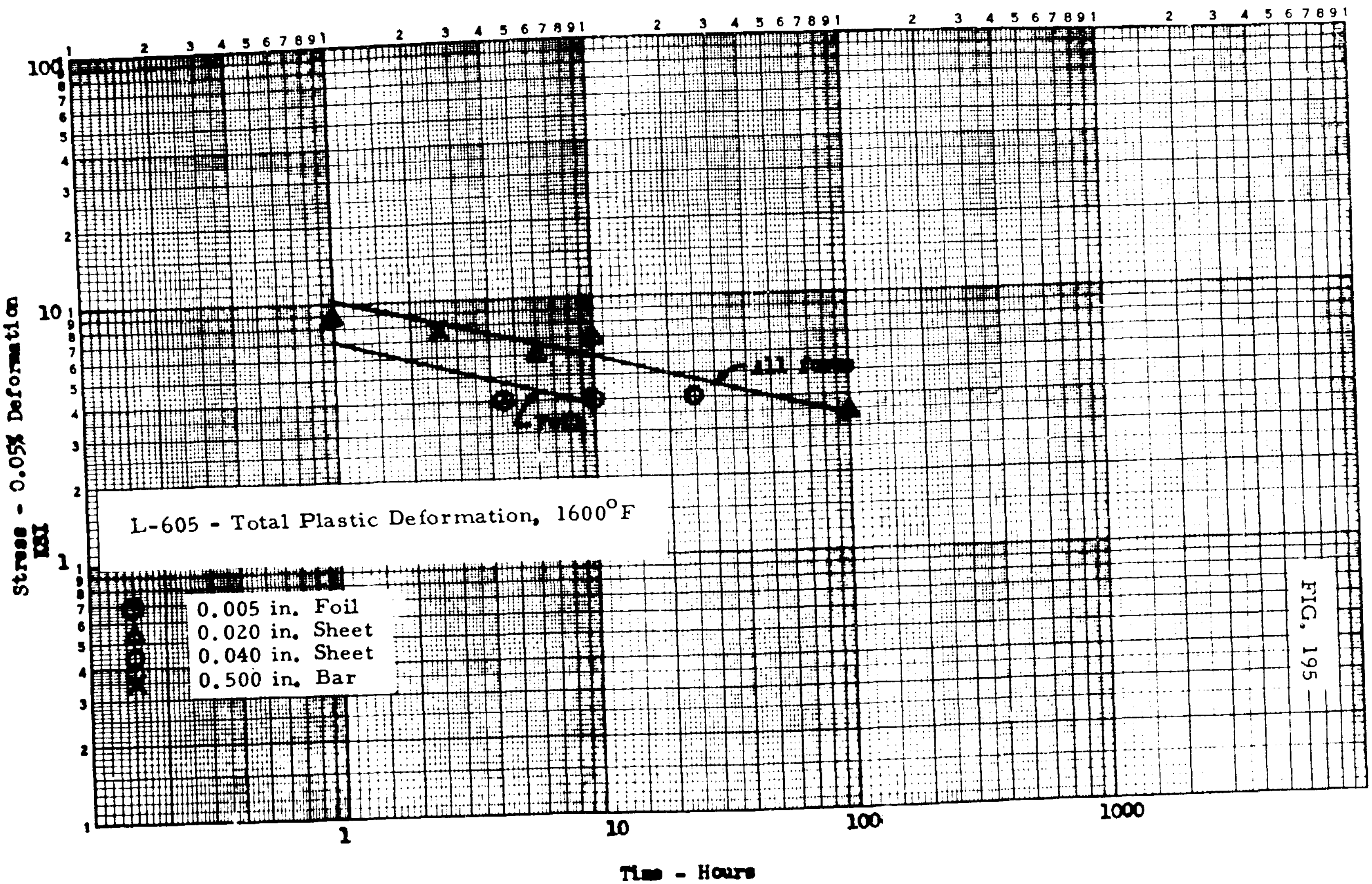


FIG. 194
L-605 - Total Plastic Deformation - 1600°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
Stress - Rupture - 0.5 in. Bar
All Forms
Foil
0.3% Deformation
0.1% Deformation
STRESS - 0.3% DEFORMATION KSI
STRESS - 0.1% DEFORMATION KSI
TIME - HOURS



L-605 - Total Plastic Deformation, 1600°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.500 in. Bar
All
Foil
Stress - 0.05% Deformation
KSI
Time - Hours

FIG. 195

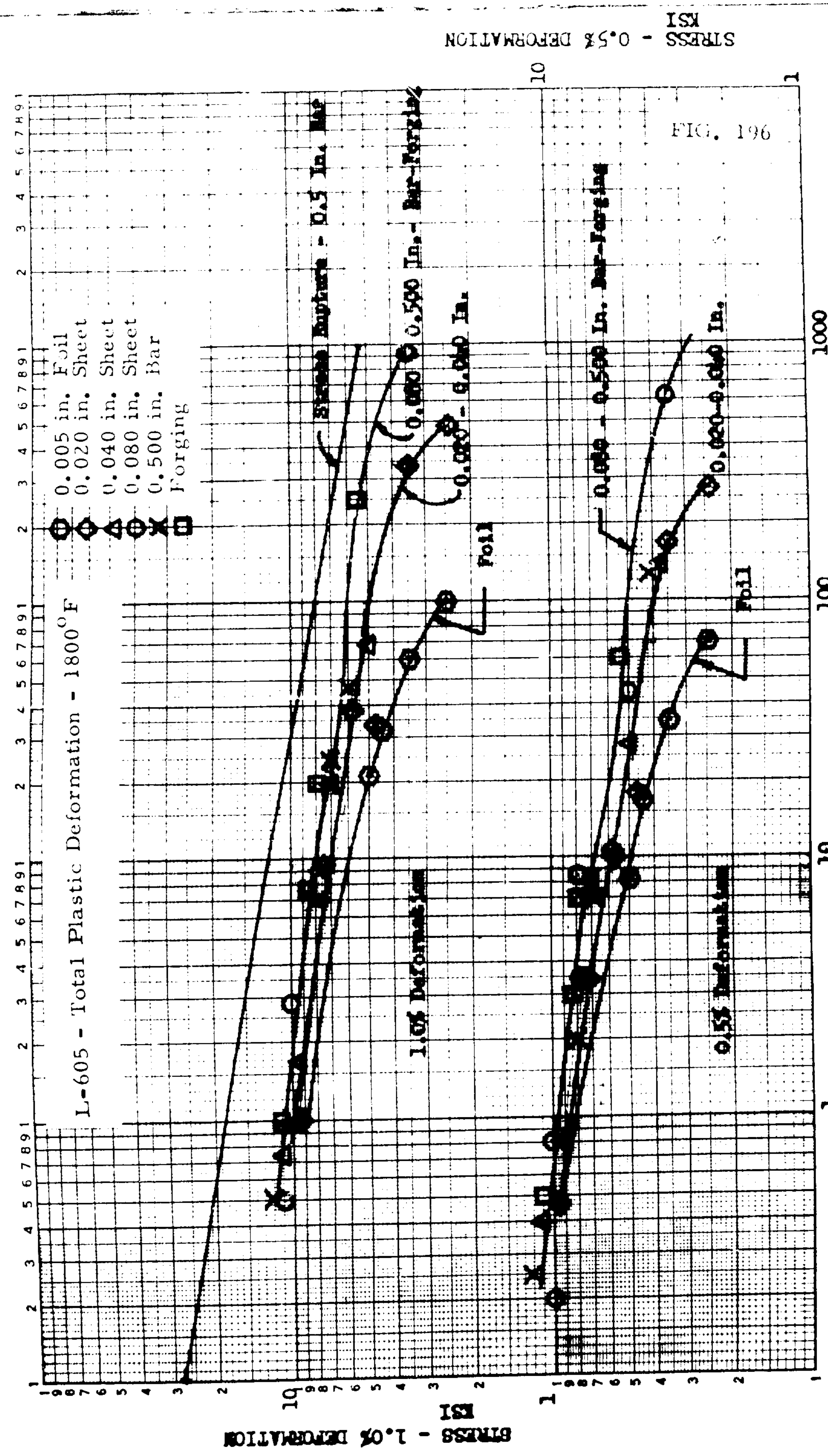

L-605 - Total Plastic Deformation - 1800°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
Stress Rupture - 0.5 In. Bar
0.080 0.500 In. - Bar-Forging
0.020 - 0.040 In.
Foil
1.0% Deformation
0.080 - 0.500 In. Bar-Forging
0.020-0.040 In.
Foil
0.5% Deformation
STRESS - 1.0% DEFORMATION
KSI
STRESS - 0.5% DEFORMATION
KSI

FIG. 196

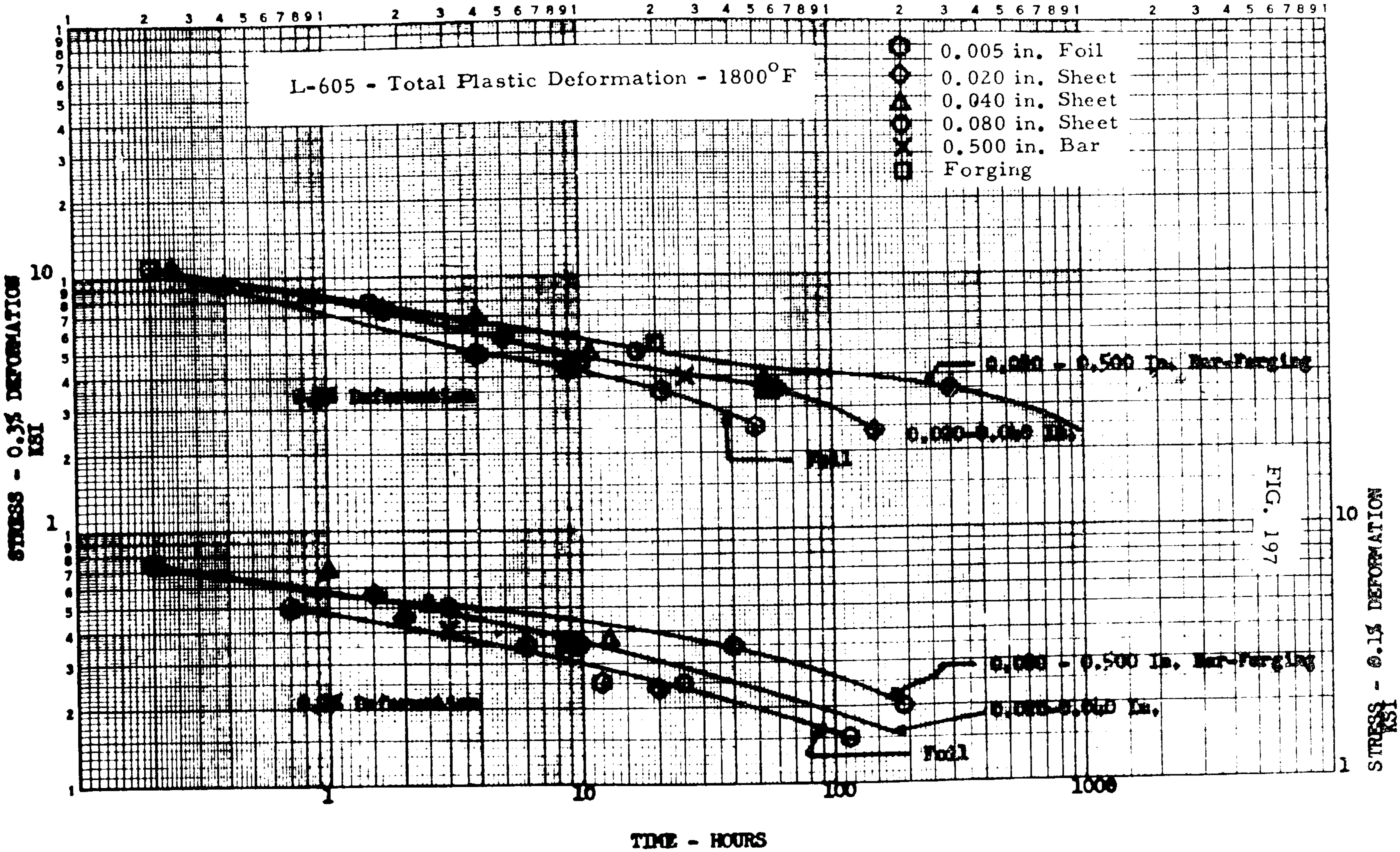

L-605 - Total Plastic Deformation - 1800°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.080 in. Sheet
0.500 in. Bar
Forging
0.080 - 0.500 In. Bar-Forging
0.020-0.040 In.
Foil
STRESS - 0.3% DEFORMATION KSI
STRESS - 0.1% DEFORMATION KSI
TIME - HOURS

FIG. 197

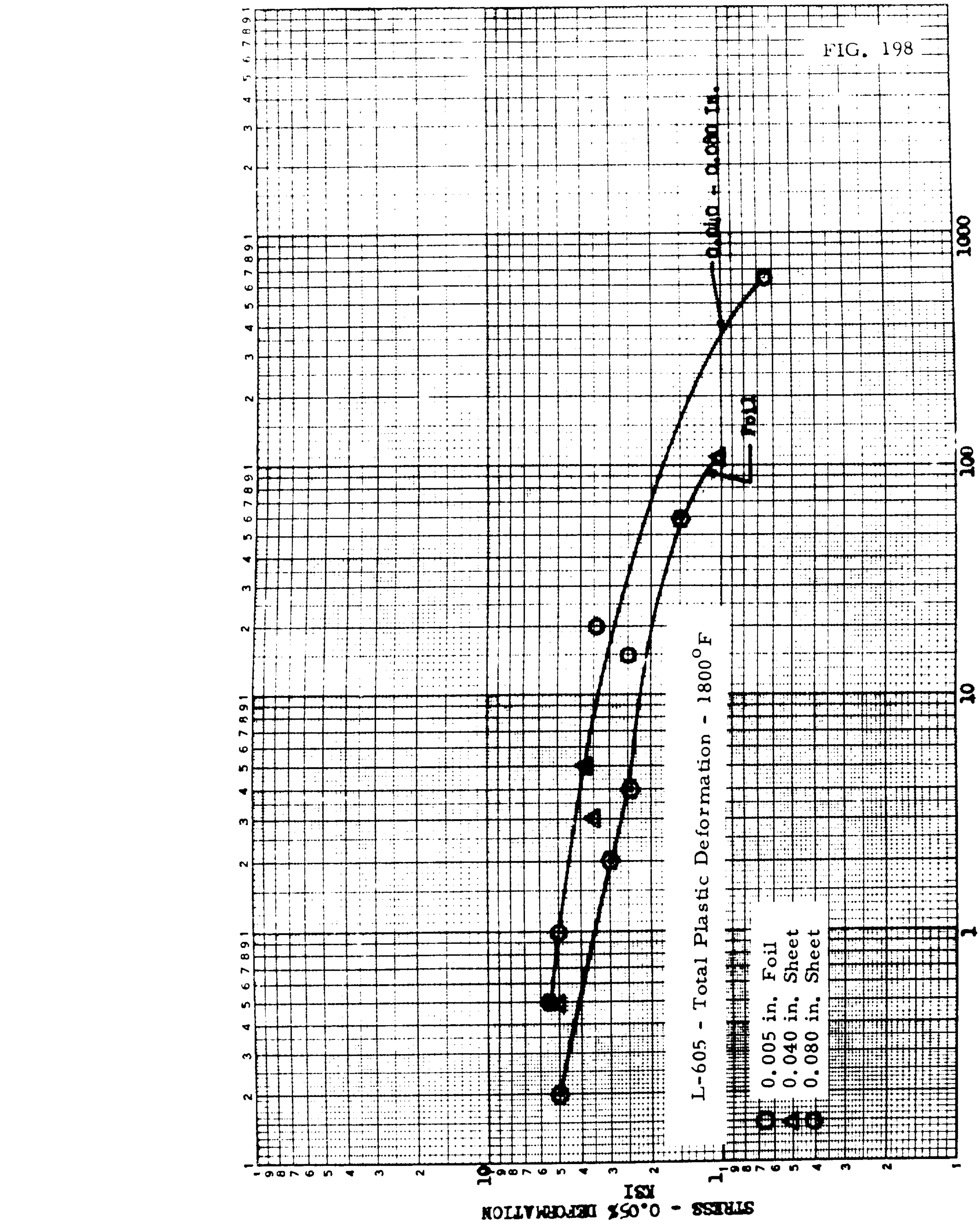
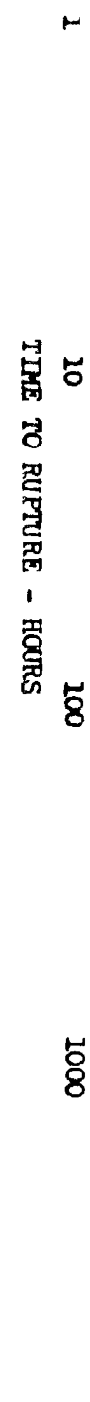


FIG. 198
L-605 - Total Plastic Deformation - 1800°F
0.005 in. Foil
0.040 in. Sheet
0.080 in. Sheet
0.040 - 0.080 In.
Foil
STRESS - 0.05% DEFORMATION
KSI
1
10
100
1000

SECTION 7.2.6 STRESS RUPTURE



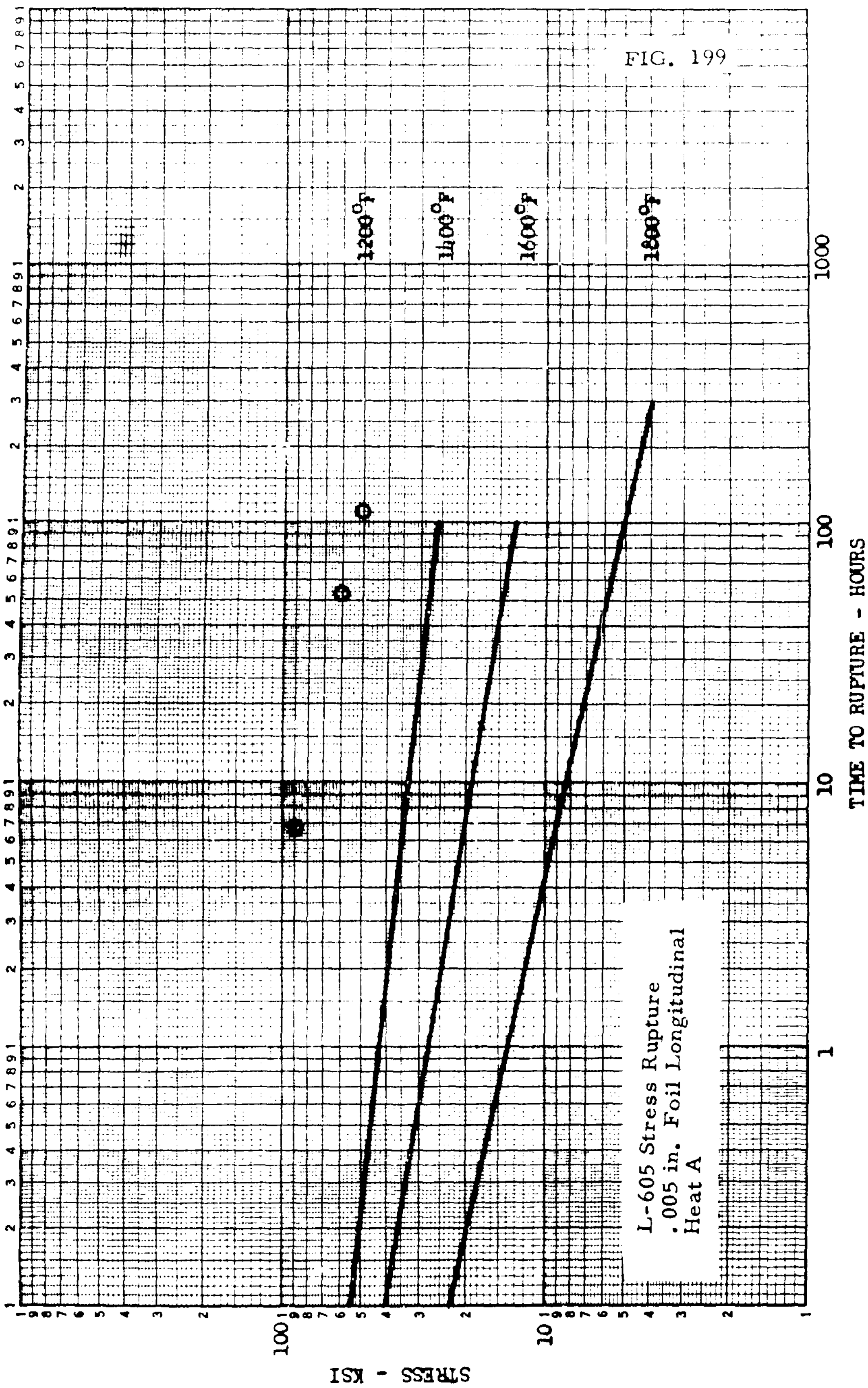


FIG. 199
1200°F
1400°F
1600°F
1800°F
L-605 Stress Rupture
.005 in. Foil Longitudinal
Heat A
TIME TO RUPTURE - HOURS
1
10
100
1000
STRESS - KSI
100
10

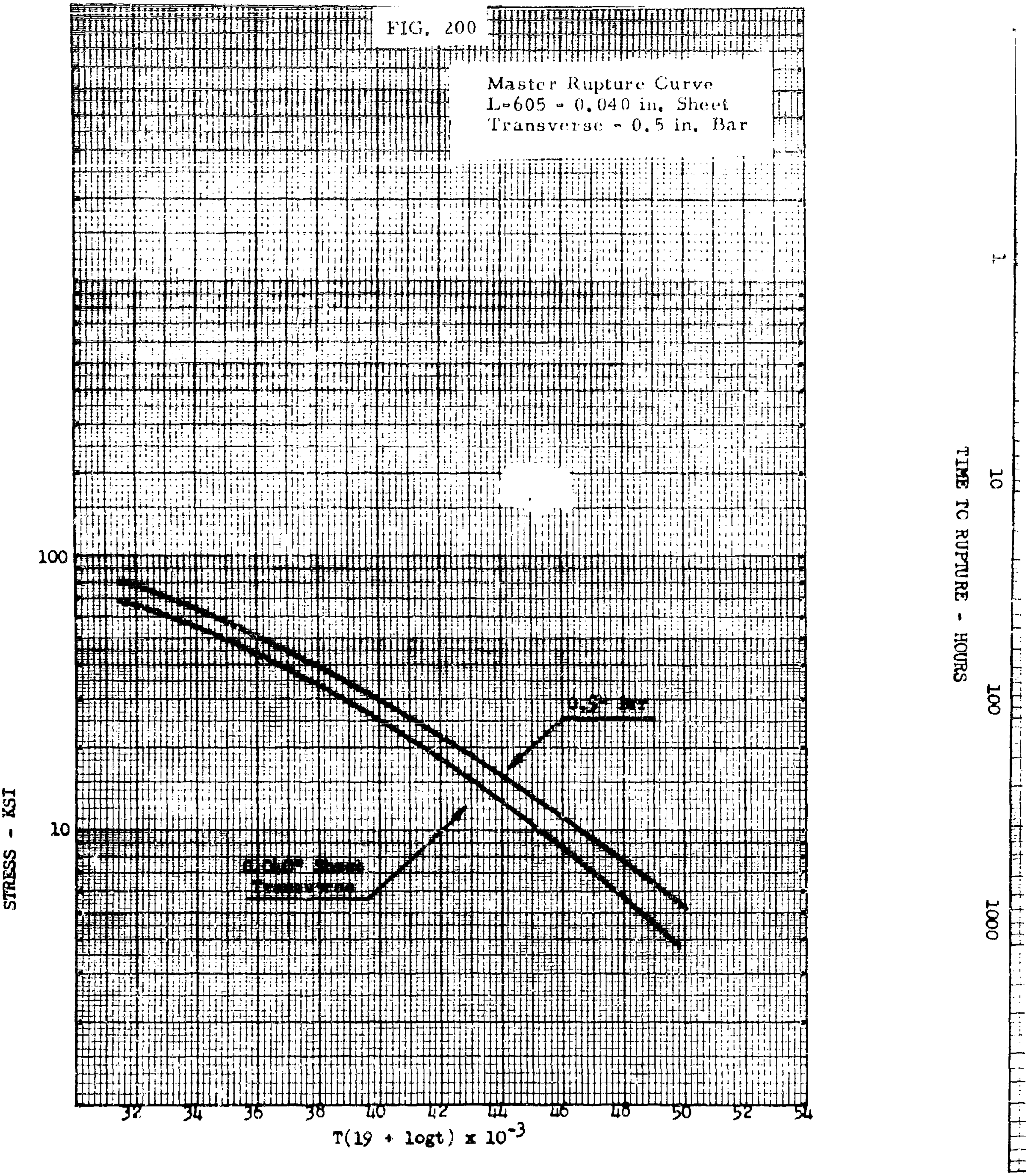


FIG. 200
Master Rupture Curve
L-605 - 0.040 in. Sheet
Transverse - 0.5 in. Bar
STRESS - KSI
100
10
32
34
36
38
40
42
44
46
48
50
52
54
T(19 + logt) x 10^{-3}
TIME TO RUPTURE - HOURS
1
10
100
1000

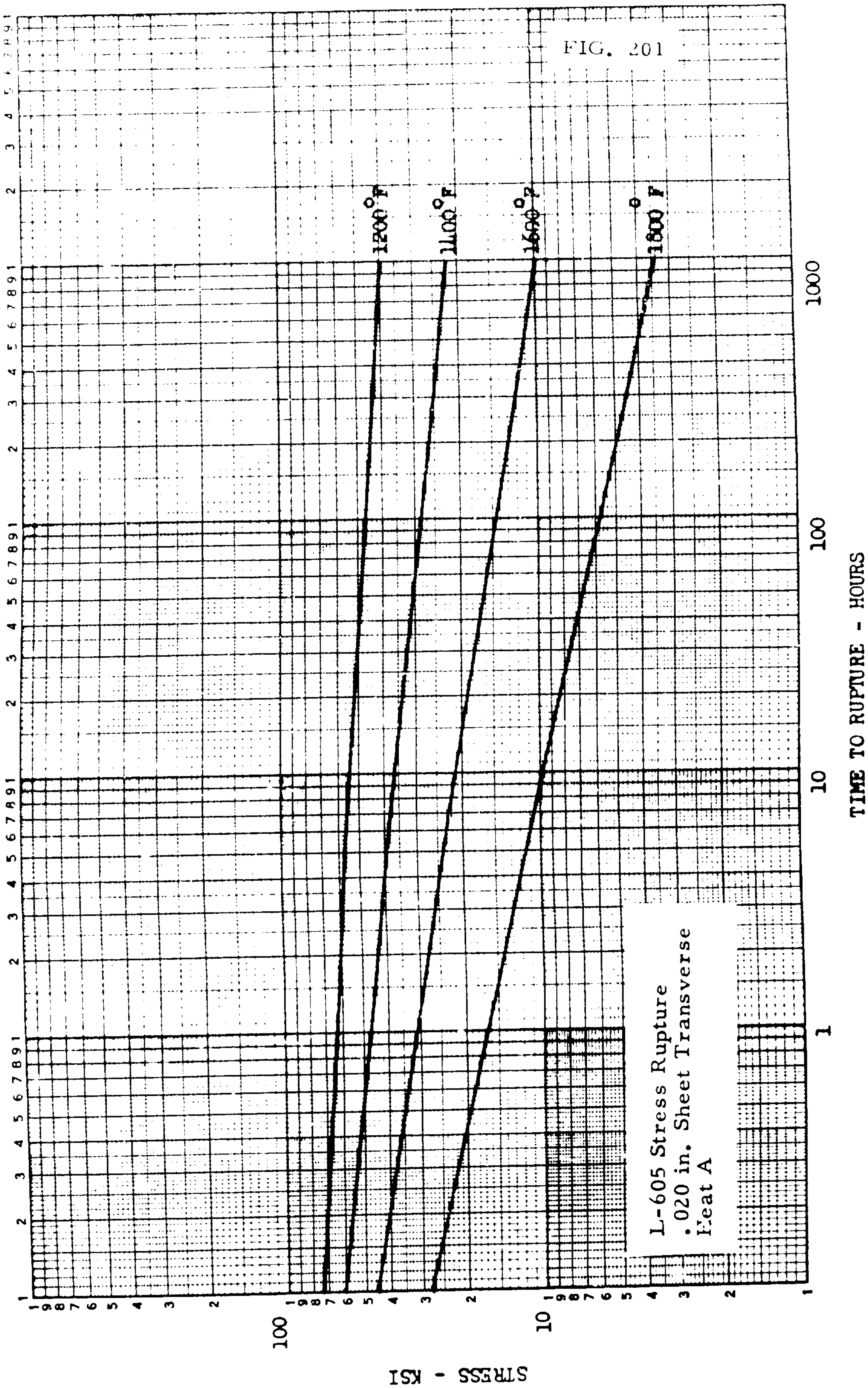
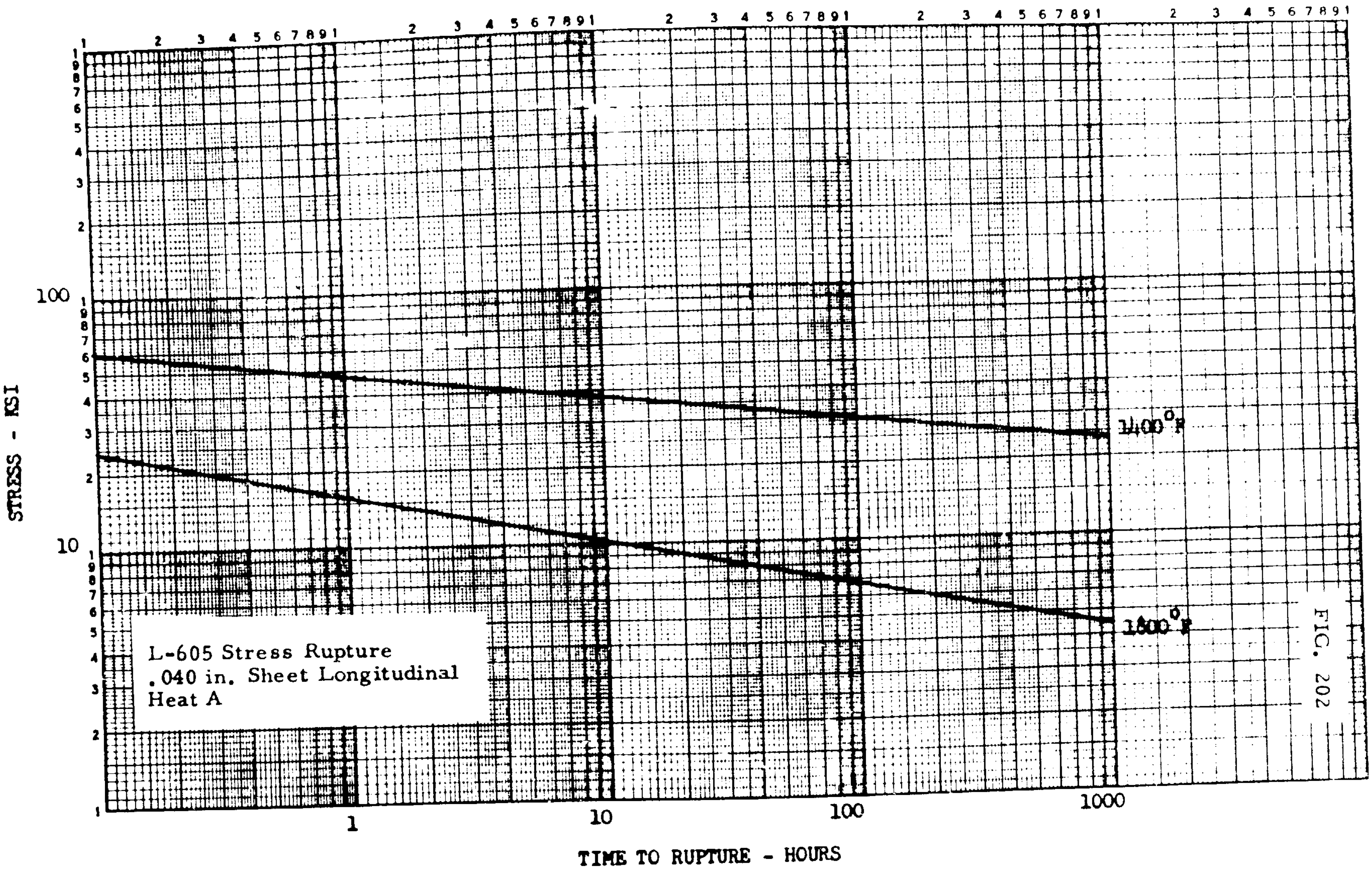
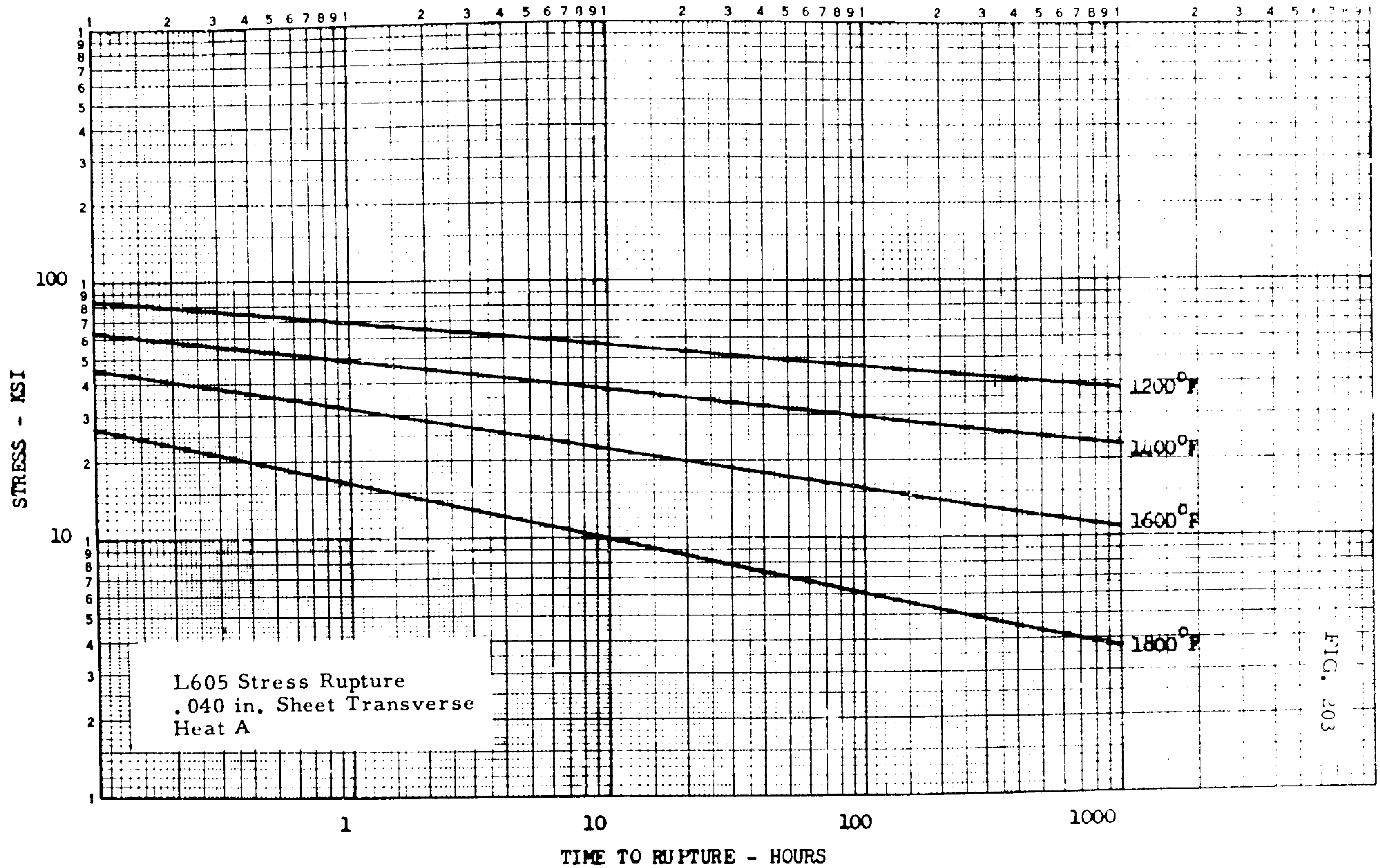


FIG. 201
L-605 Stress Rupture
.020 in. Sheet Transverse
Heat A
1200°F
1400°F
1600°F
1800°F
TIME TO RUPTURE - HOURS
1
10
100
1000
STRESS - KSI
10
100

FIG. 202

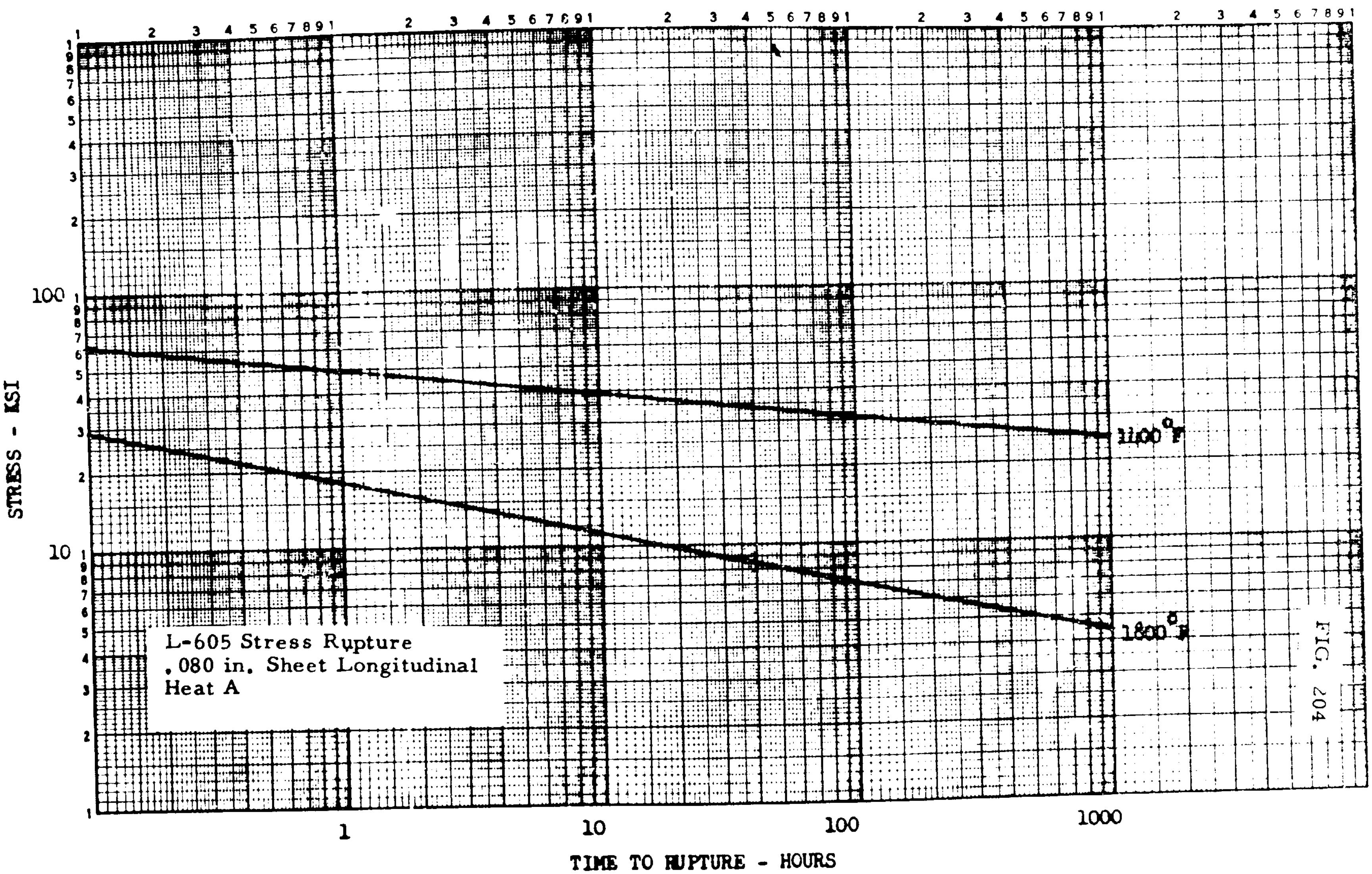


L-605 Stress Rupture
.040 in. Sheet Longitudinal
Heat A
1400°F
1800°F
STRESS - KSI
TIME TO RUPTURE - HOURS
100
10
1
10
100
1000



L605 Stress Rupture
.040 in. Sheet Transverse
Heat A
1200°F
1400°F
1600°F
1800°F
STRESS - KSI
TIME TO RUPTURE - HOURS

FIG. 203



L-605 Stress Rupture
.080 in. Sheet Longitudinal
Heat A
1100°F
1800°F
STRESS - KSI
TIME TO RUPTURE - HOURS

FIG. 204

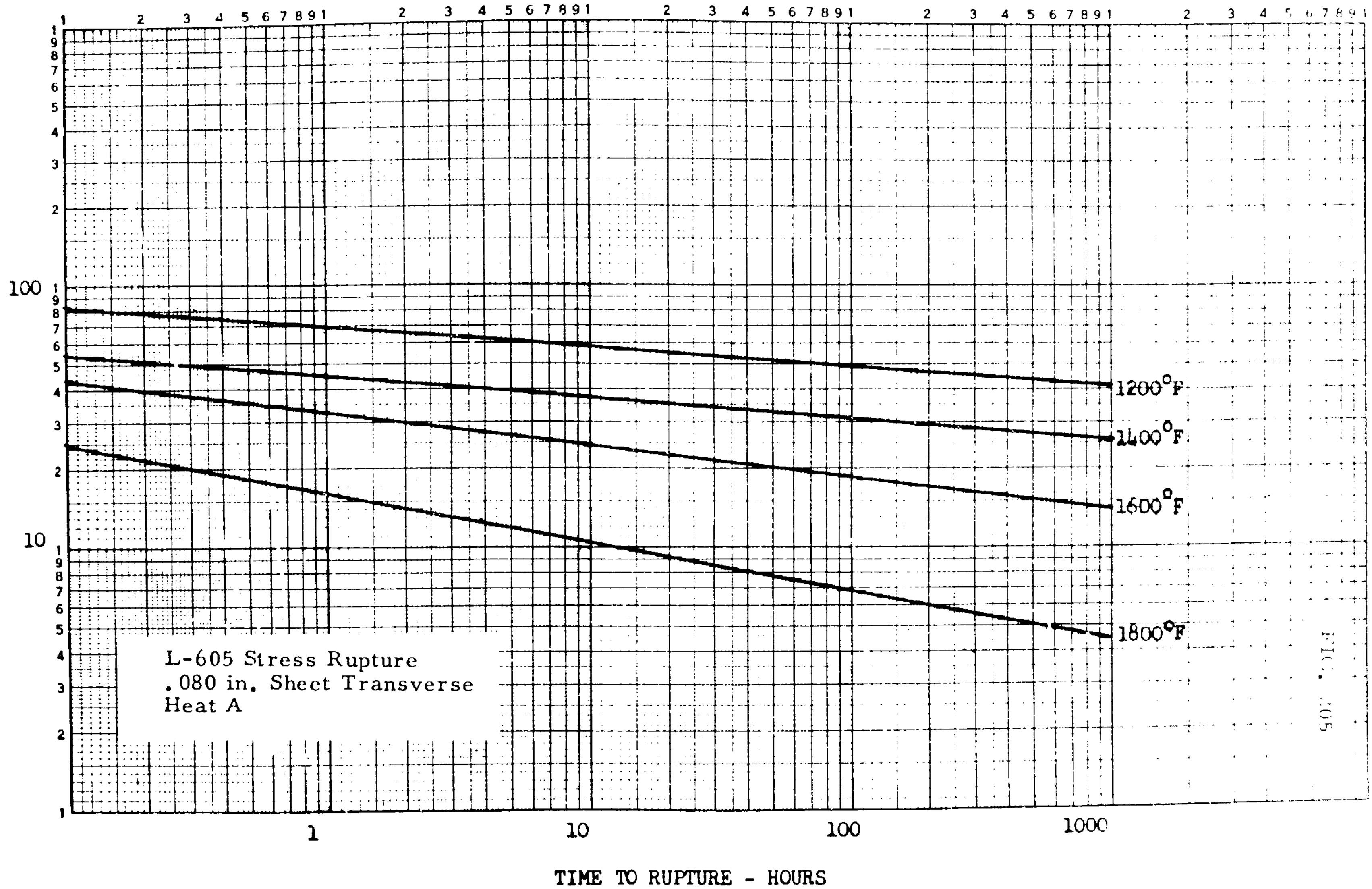


FIG. 205
L-605 Stress Rupture
.080 in. Sheet Transverse
Heat A
1200°F
1400°F
1600°F
1800°F
STRESS - KSI
100
10
TIME TO RUPTURE - HOURS
1
10
100
1000

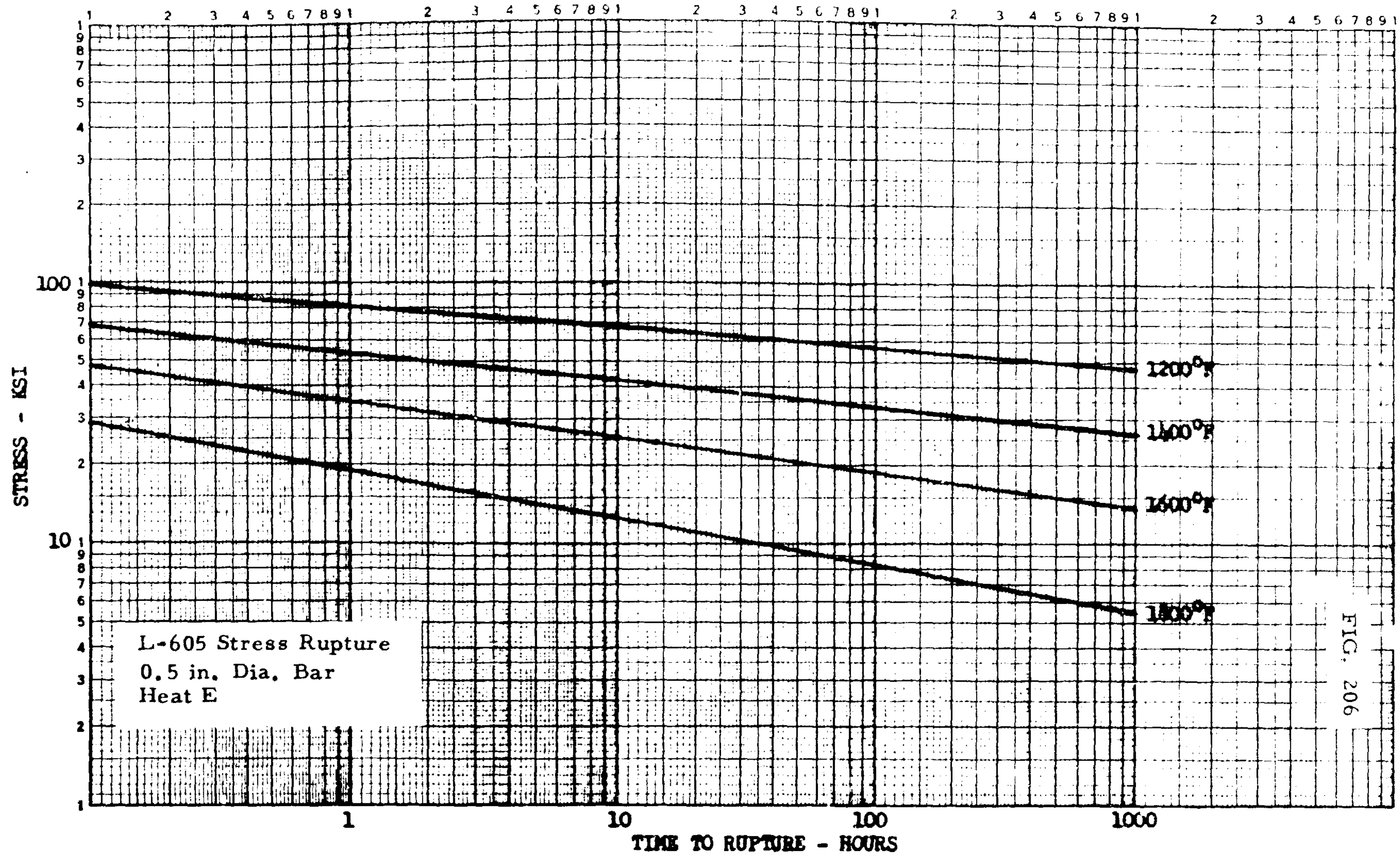
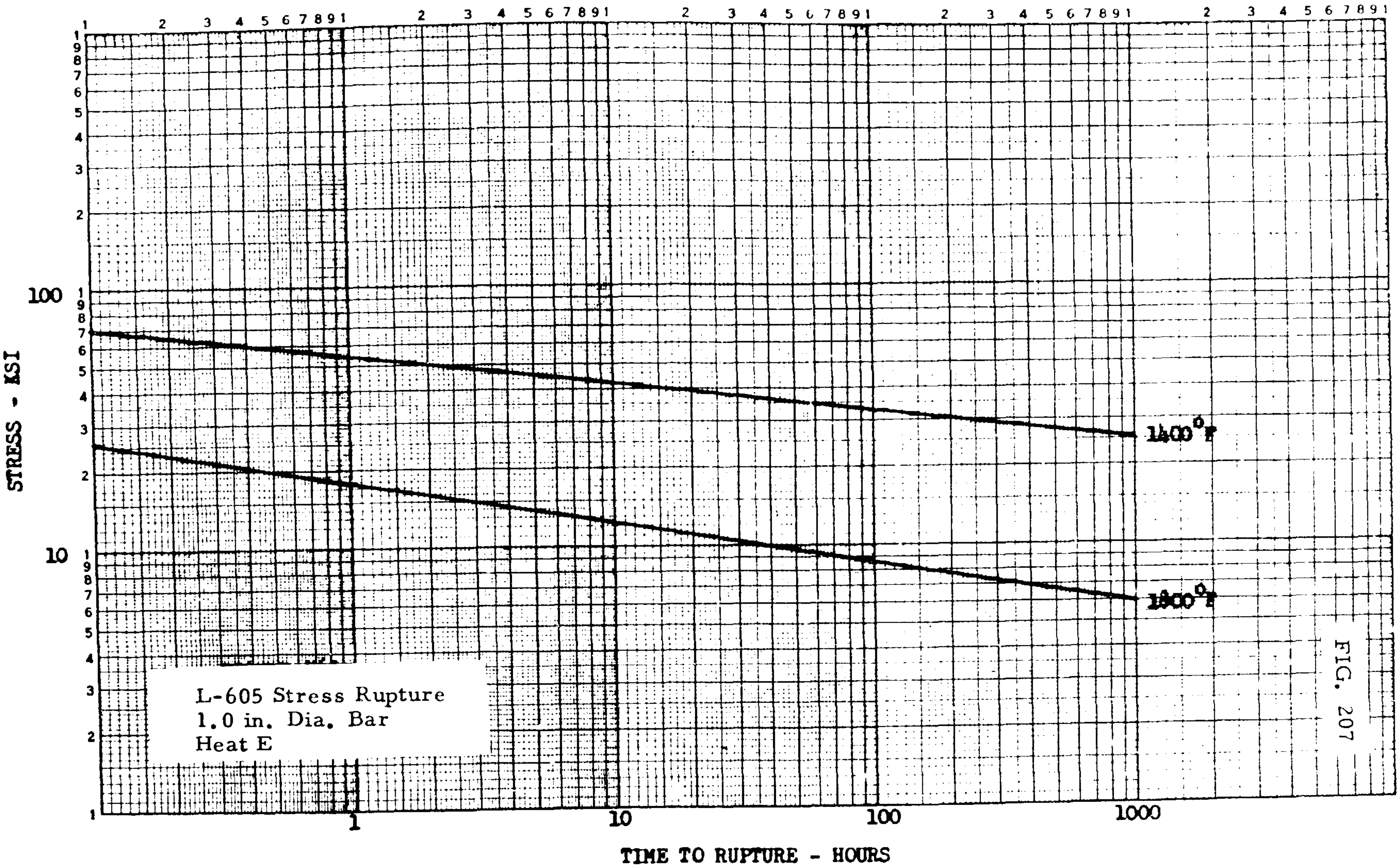

L-605 Stress Rupture
0.5 in. Dia. Bar
Heat E
1200°F
1400°F
1600°F
1800°F
STRESS - KSI
100
10
1
10
100
1000
TIME TO RUPTURE - HOURS

FIG. 206



L-605 Stress Rupture
1.0 in. Dia. Bar
Heat E
1400°F
1800°F
FIG. 207
STRESS - KSI
100
10
TIME TO RUPTURE - HOURS
1
10
100
1000

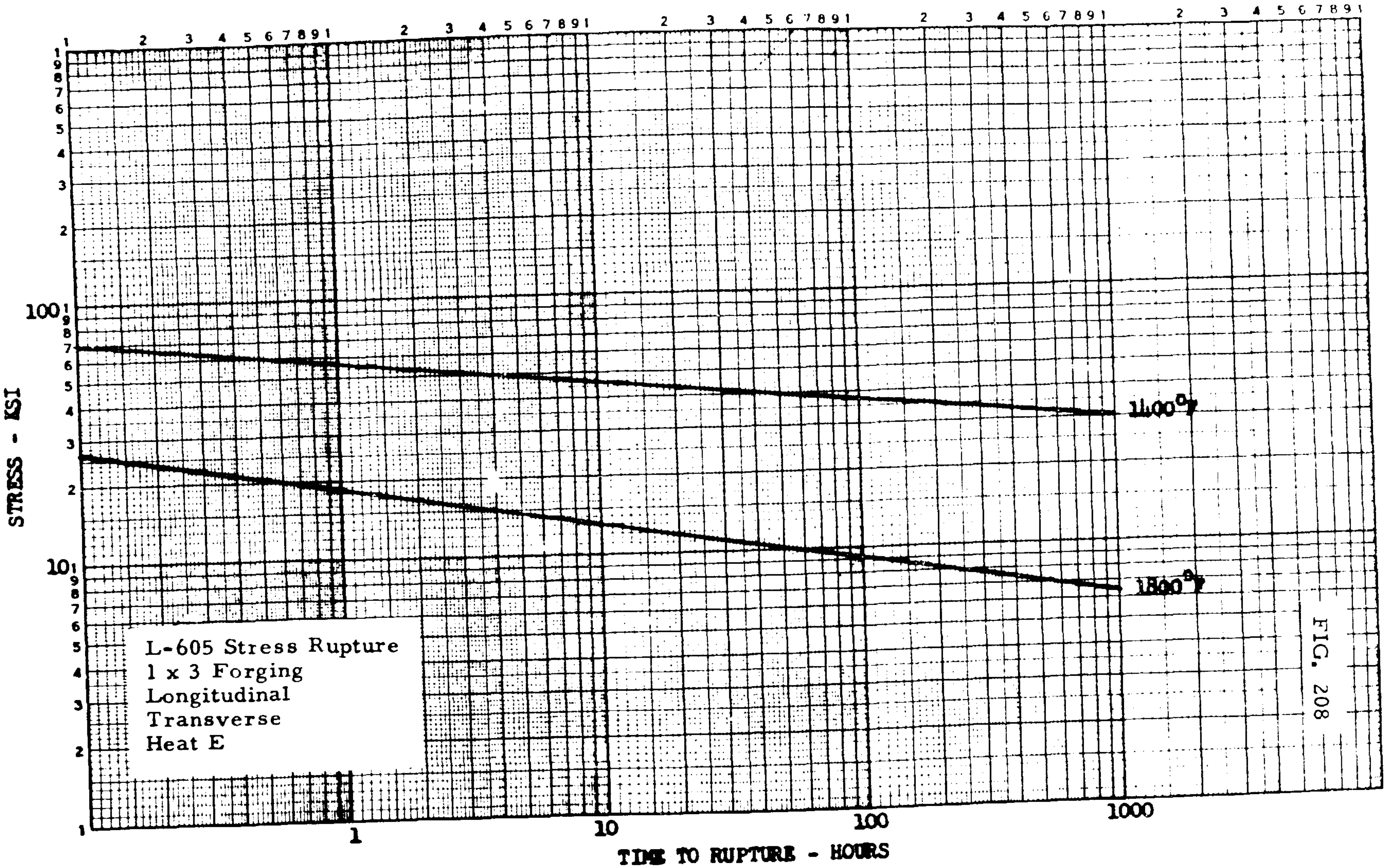
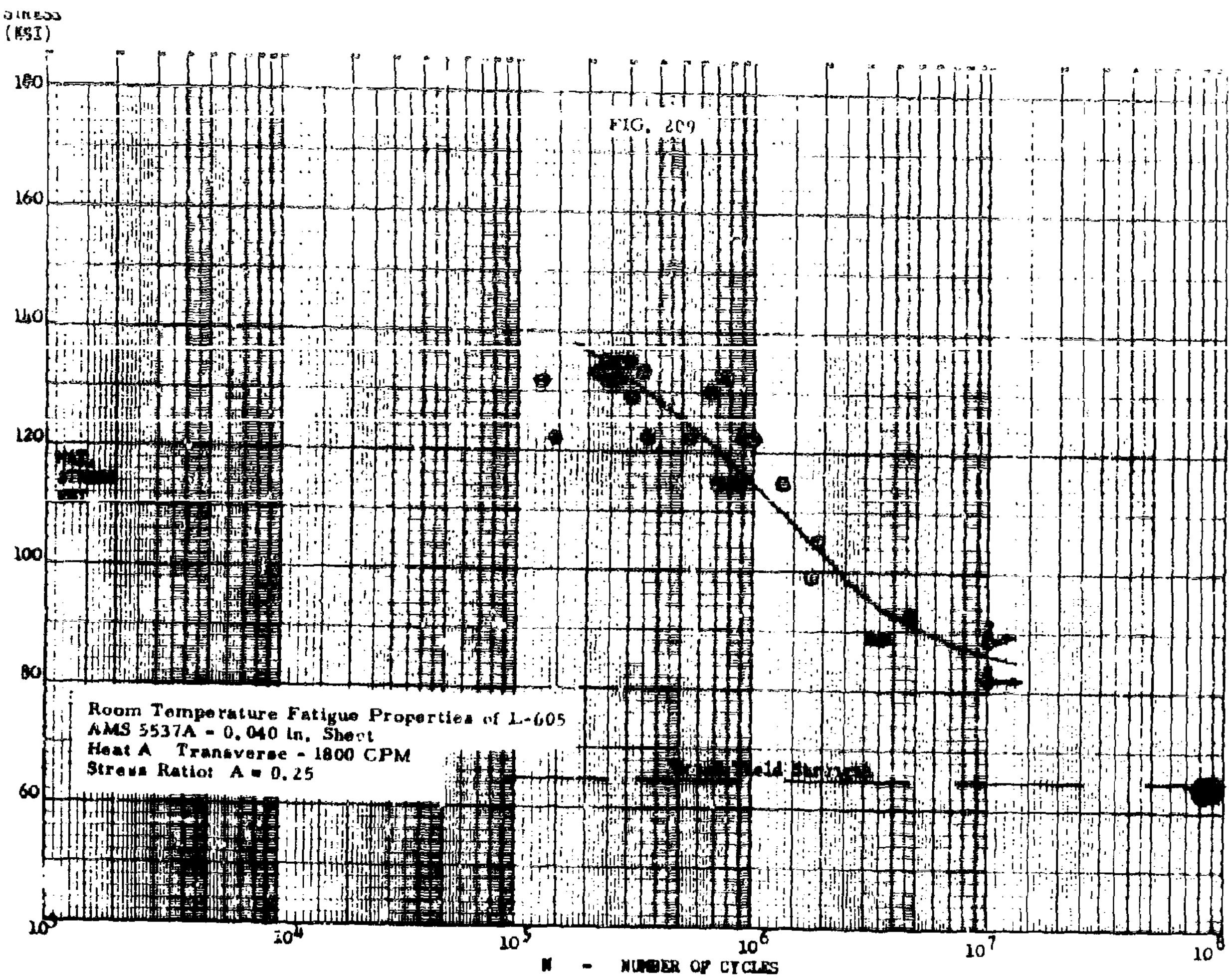
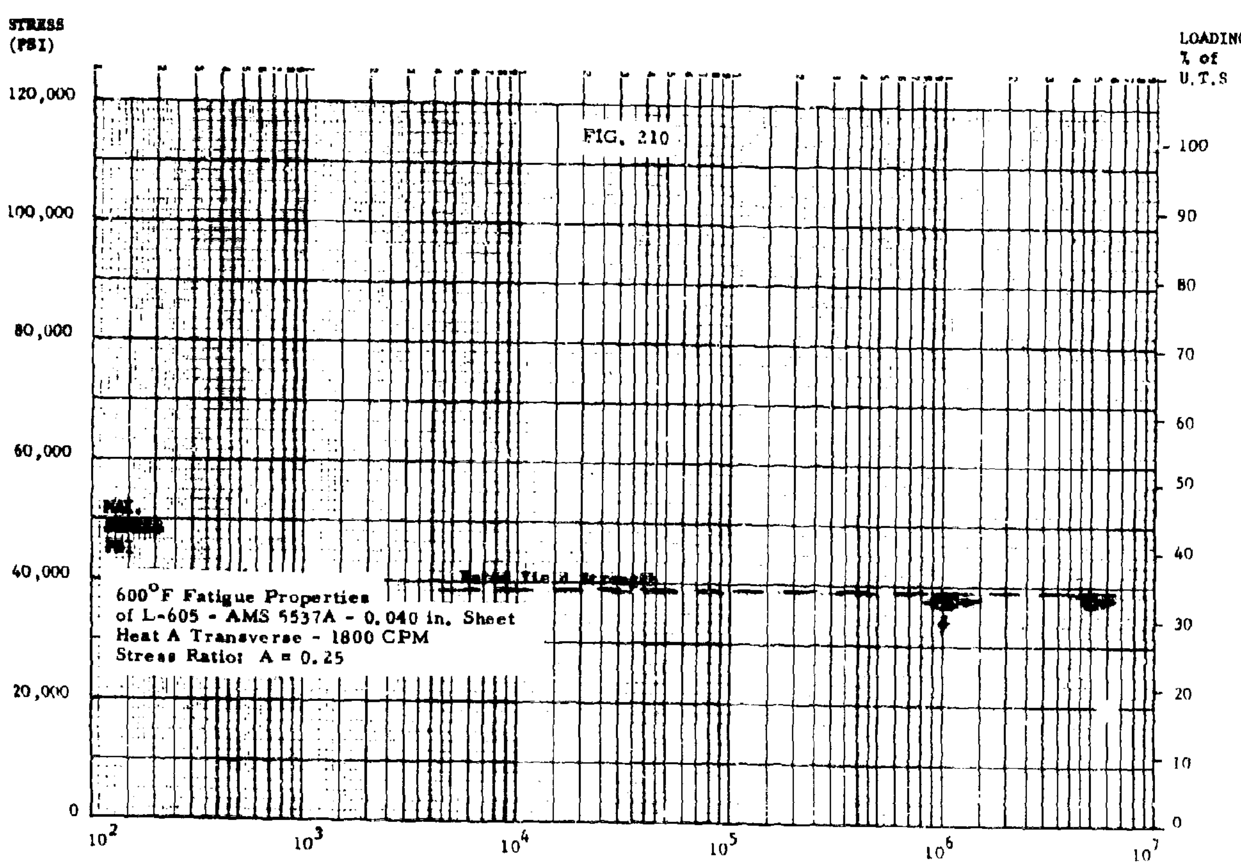

L-605 Stress Rupture
1 x 3 Forging
Longitudinal
Transverse
Heat E
1100°F
1800°F
STRESS - KSI
TIME TO RUPTURE - HOURS
1
10
100
1000

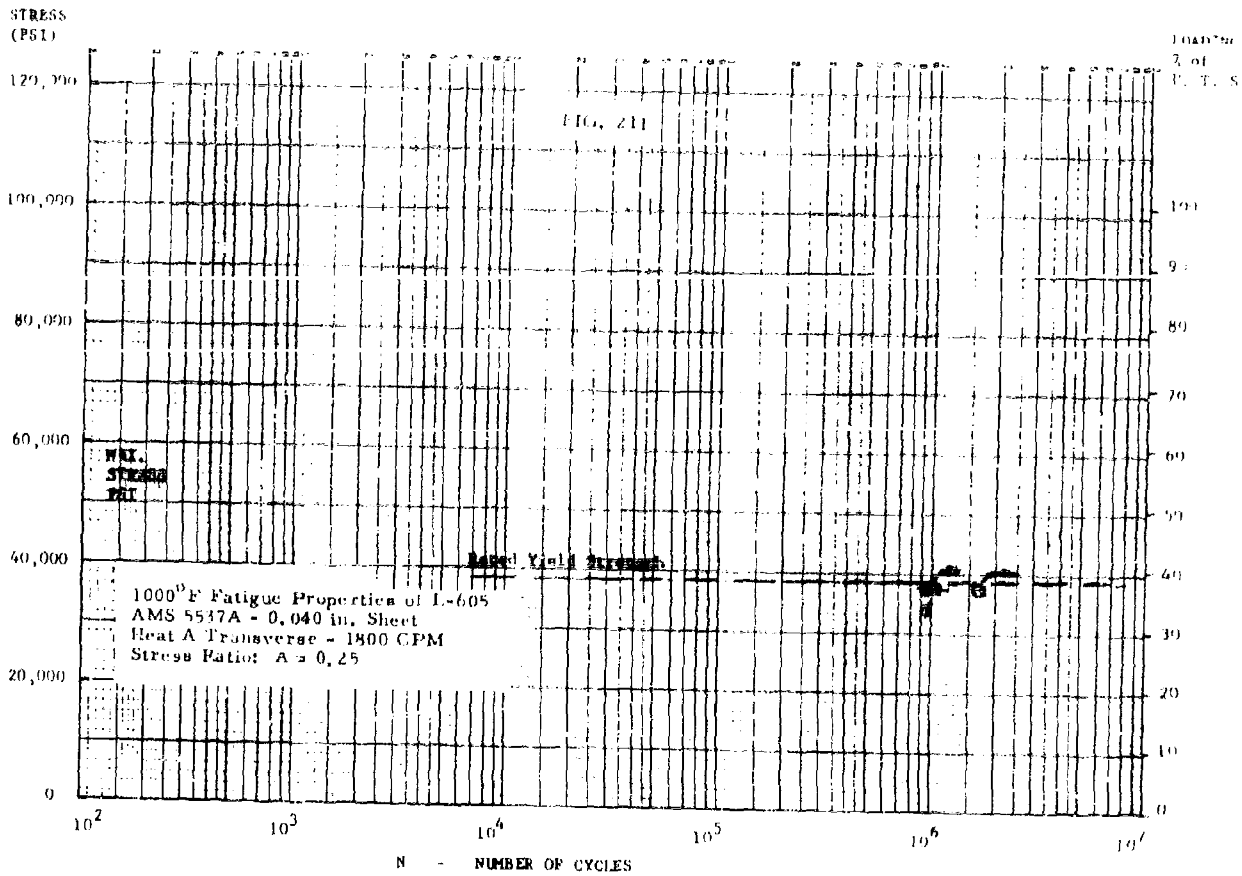
FIG. 208

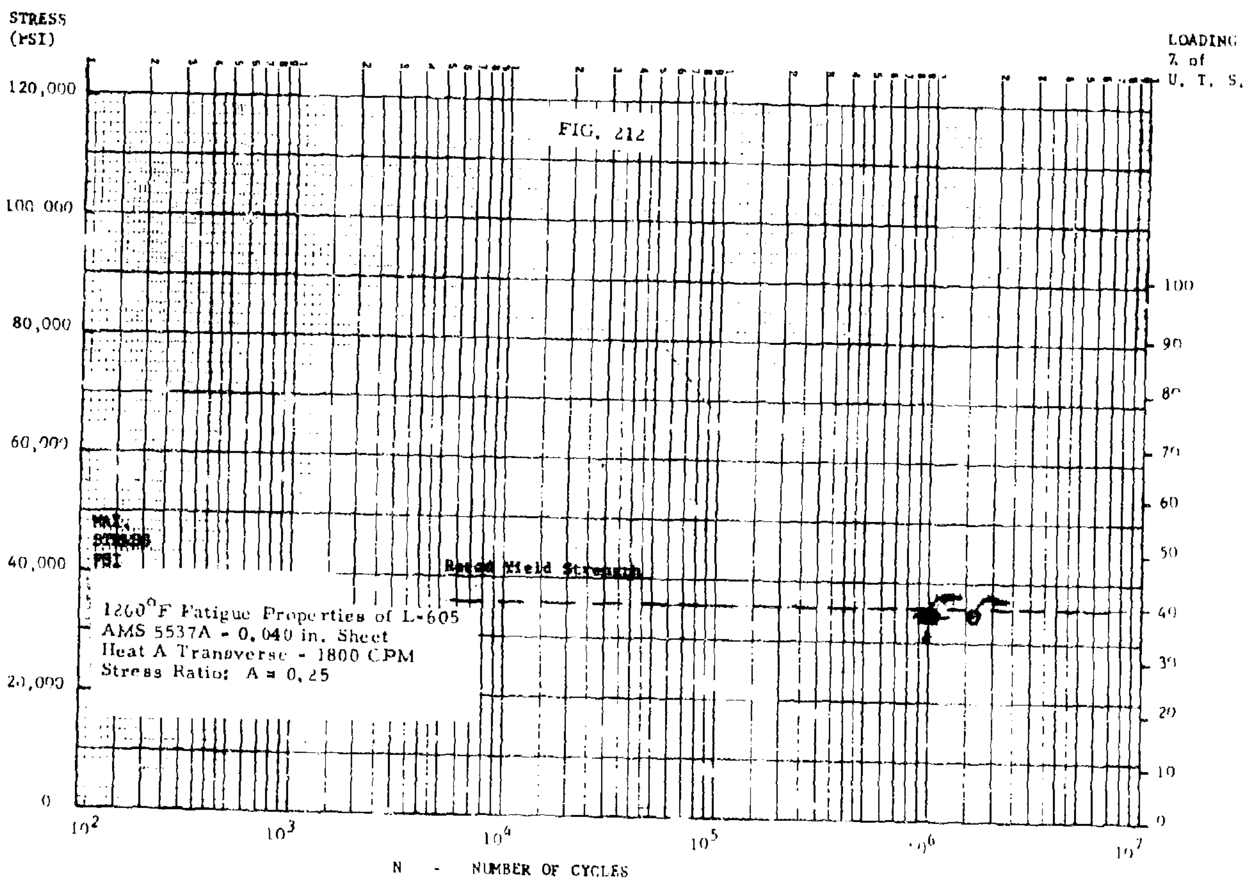
SECTION VII

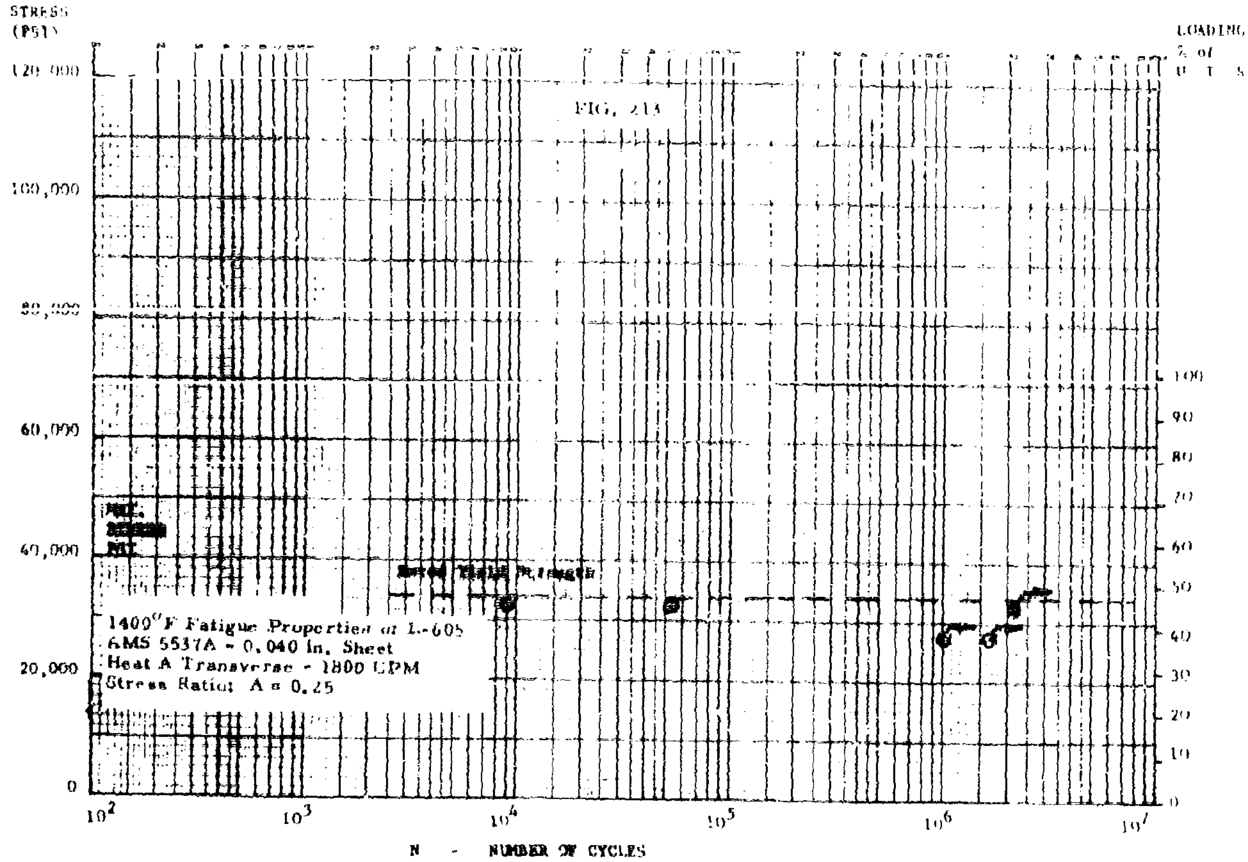
SECTION 7.2.7 FATIGUE

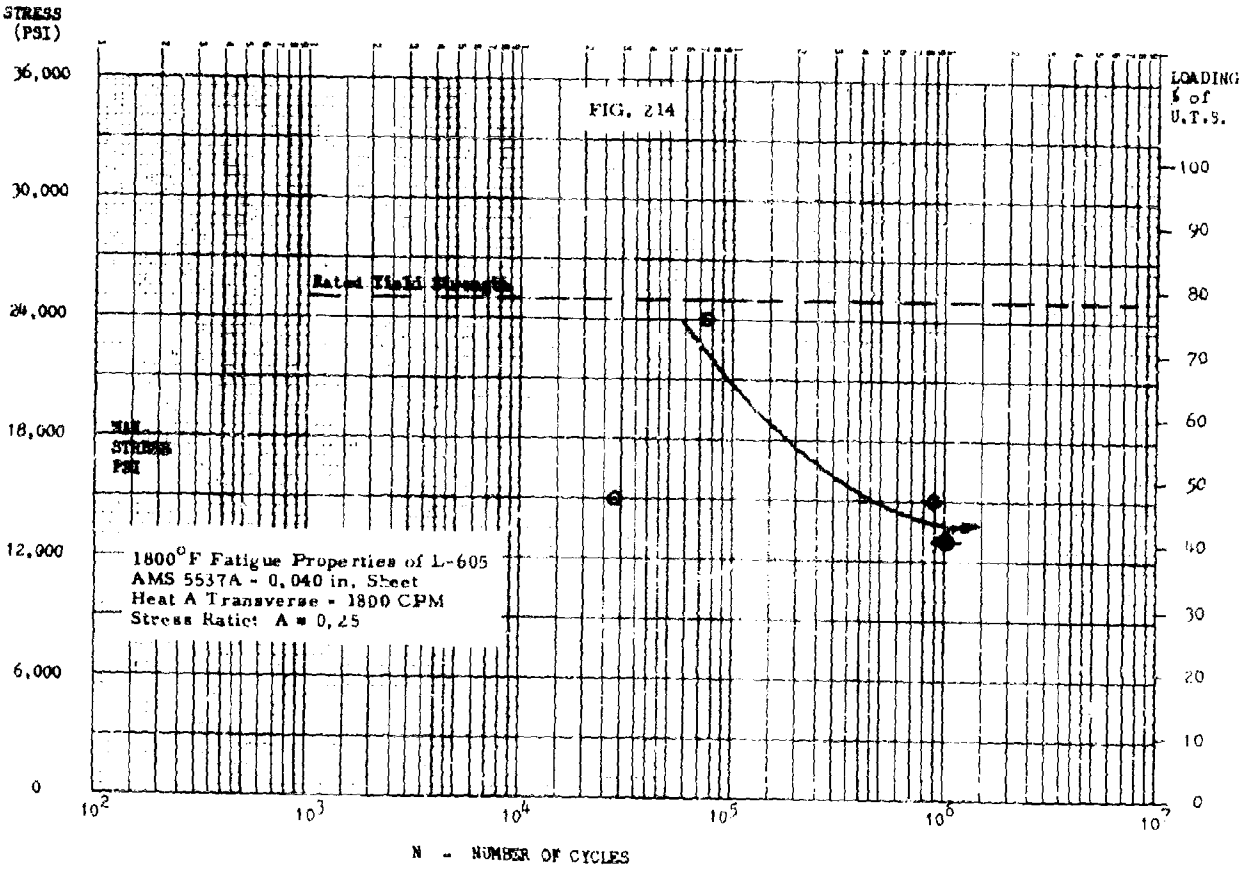

STRESS
(KSI)
180
160
140
120
100
80
60
40
FIG. 209
Room Temperature Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^3
10^4
10^5
10^6
10^7
10^8
N - NUMBER OF CYCLES


STRESS
(PSI)
LOADING
% of
U.T.S
120,000
100,000
80,000
60,000
40,000
20,000
0
100
90
80
70
60
50
40
30
20
10
0
FIG. 210
Rated Yield Strength
600°F Fatigue Properties
of L-605 - AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES


STRESS (PSI)
LOADING % of U. T. S.
FIG. 211
MAX. STRESS PSI
Rated Yield Strength
1000°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
N - NUMBER OF CYCLES


STRESS (PSI)
LOADING % of U. T. S.
FIG. 212
MAX. STRESS PSI
Rated Yield Strength
1200°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
N - NUMBER OF CYCLES


STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
FIG. 213
MAX. STRESS PSI
Rated Yield Strength
1400°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES


STRESS (PSI)
36,000
30,000
24,000
18,000
12,000
6,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
FIG. 214
MAX. STRESS PSI
Rated Yield Strength
1800°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

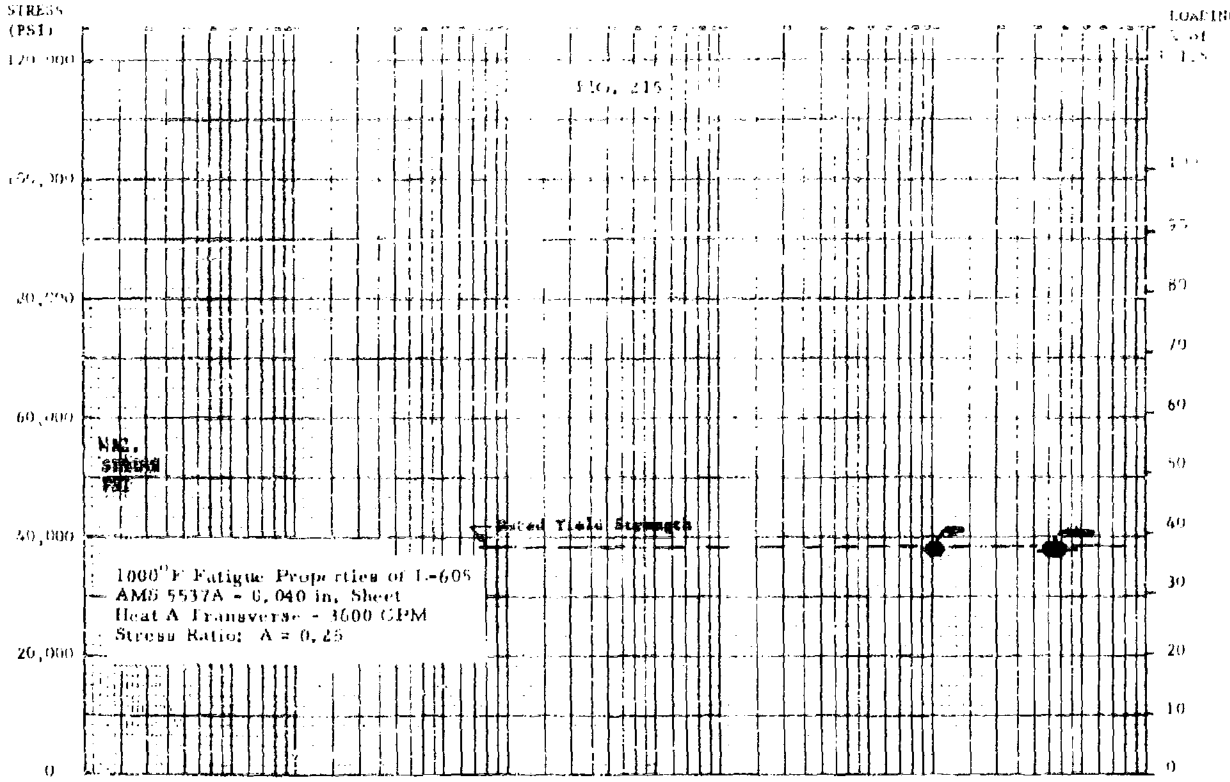


FIG. 215

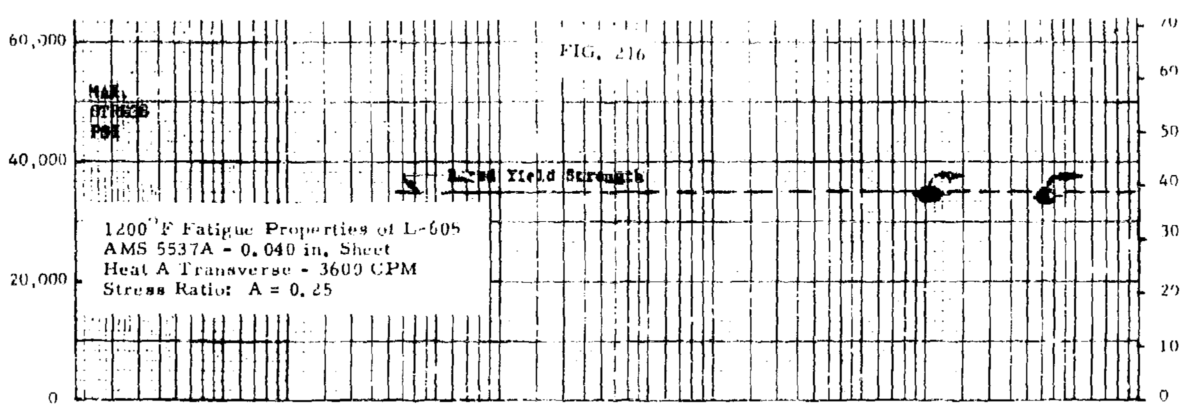


FIG. 216

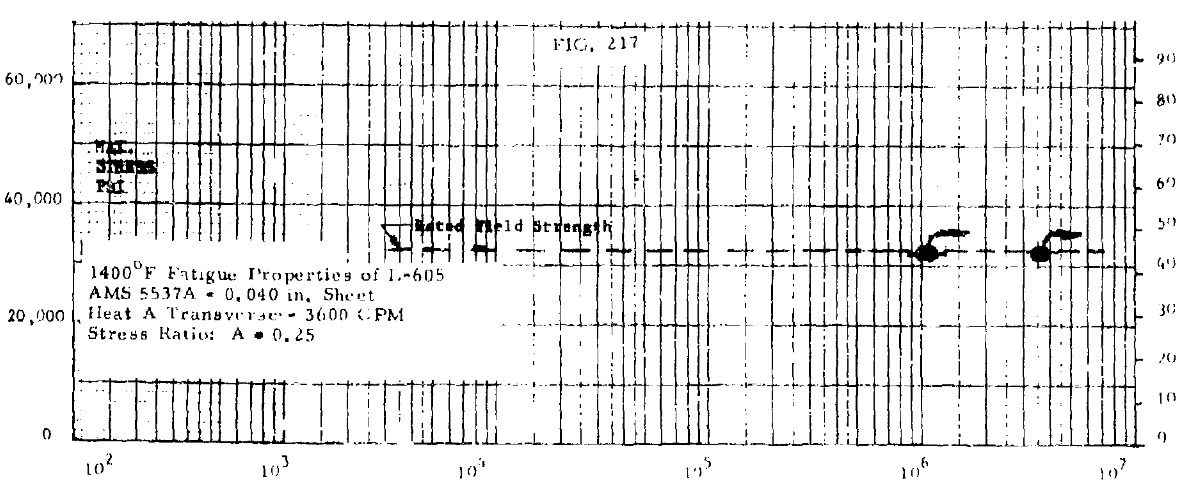
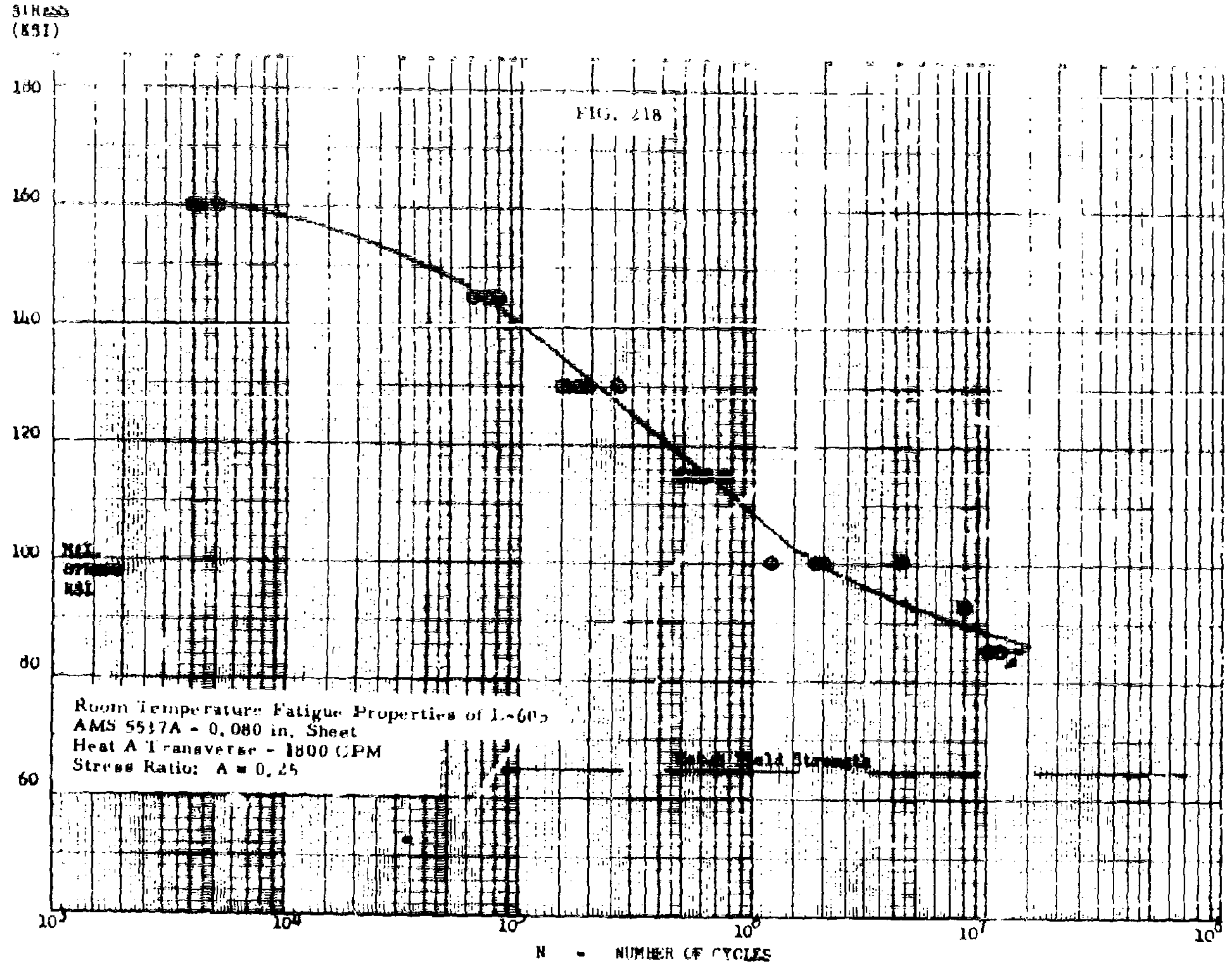


FIG. 217


STRESS (KSI)
FIG. 218
MAX. STRESS KSI
Room Temperature Fatigue Properties of L-605
AMS 5537A - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
N - NUMBER OF CYCLES

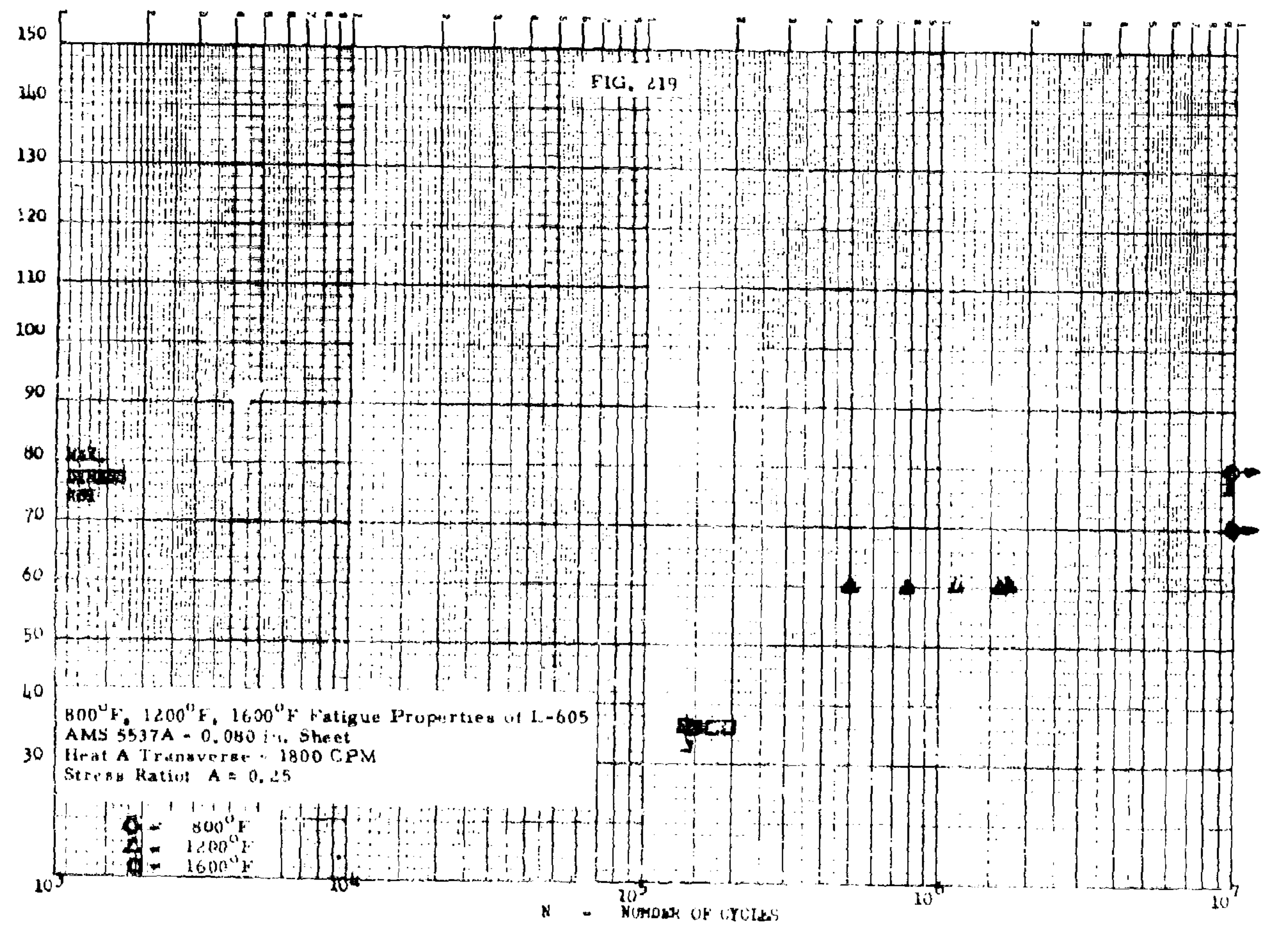


FIG. 219
MAX. STRESS KSI
800°F, 1200°F, 1600°F Fatigue Properties of L-605
AMS 5537A - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
800°F
1200°F
1600°F
N - NUMBER OF CYCLES

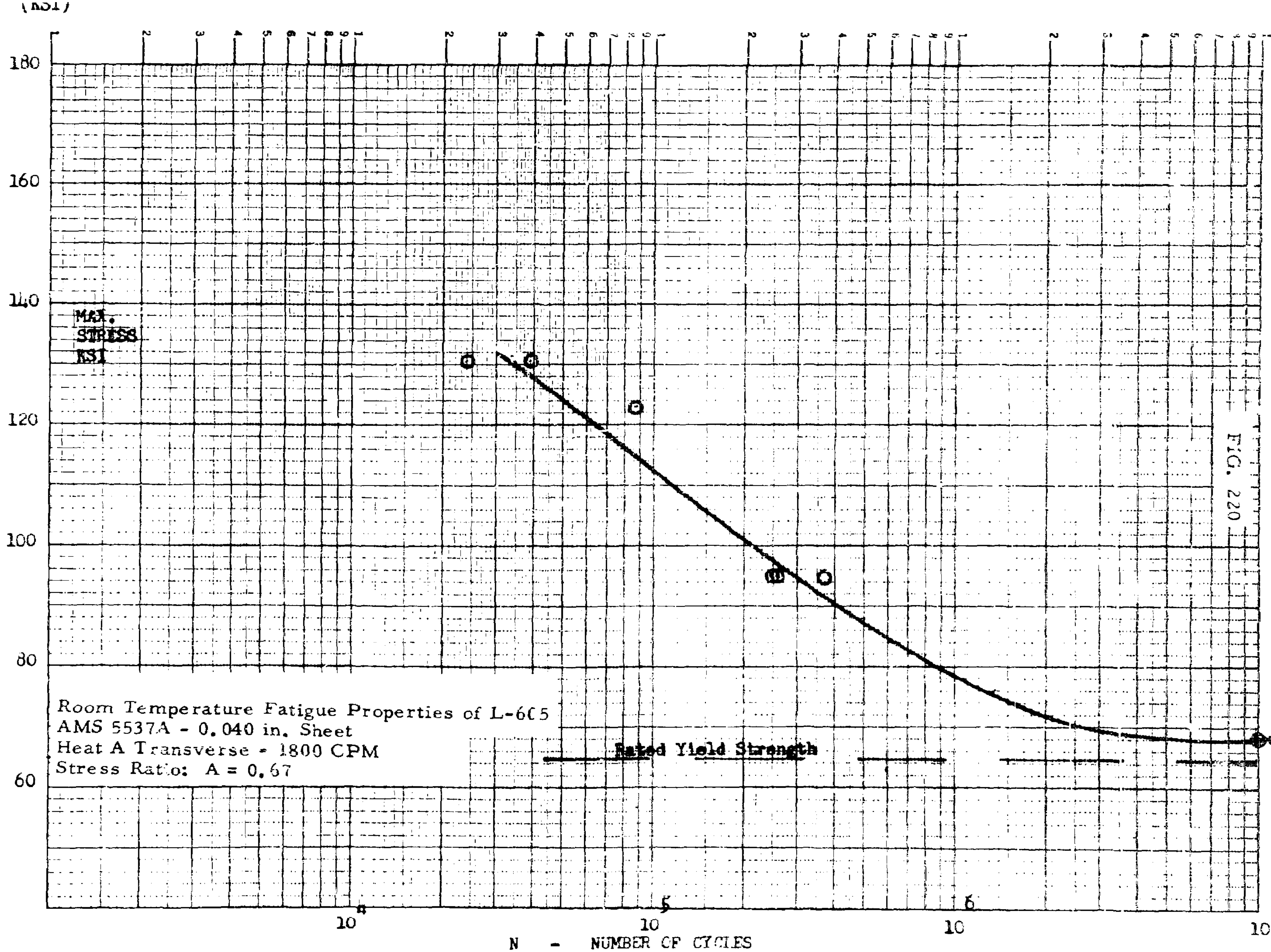


FIG. 220
Room Temperature Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
MAX. STRESS KSI
(KSI)
180
160
140
120
100
80
60
Rated Yield Strength
N - NUMBER OF CYCLES
10^4
10^5
10^6
10^7

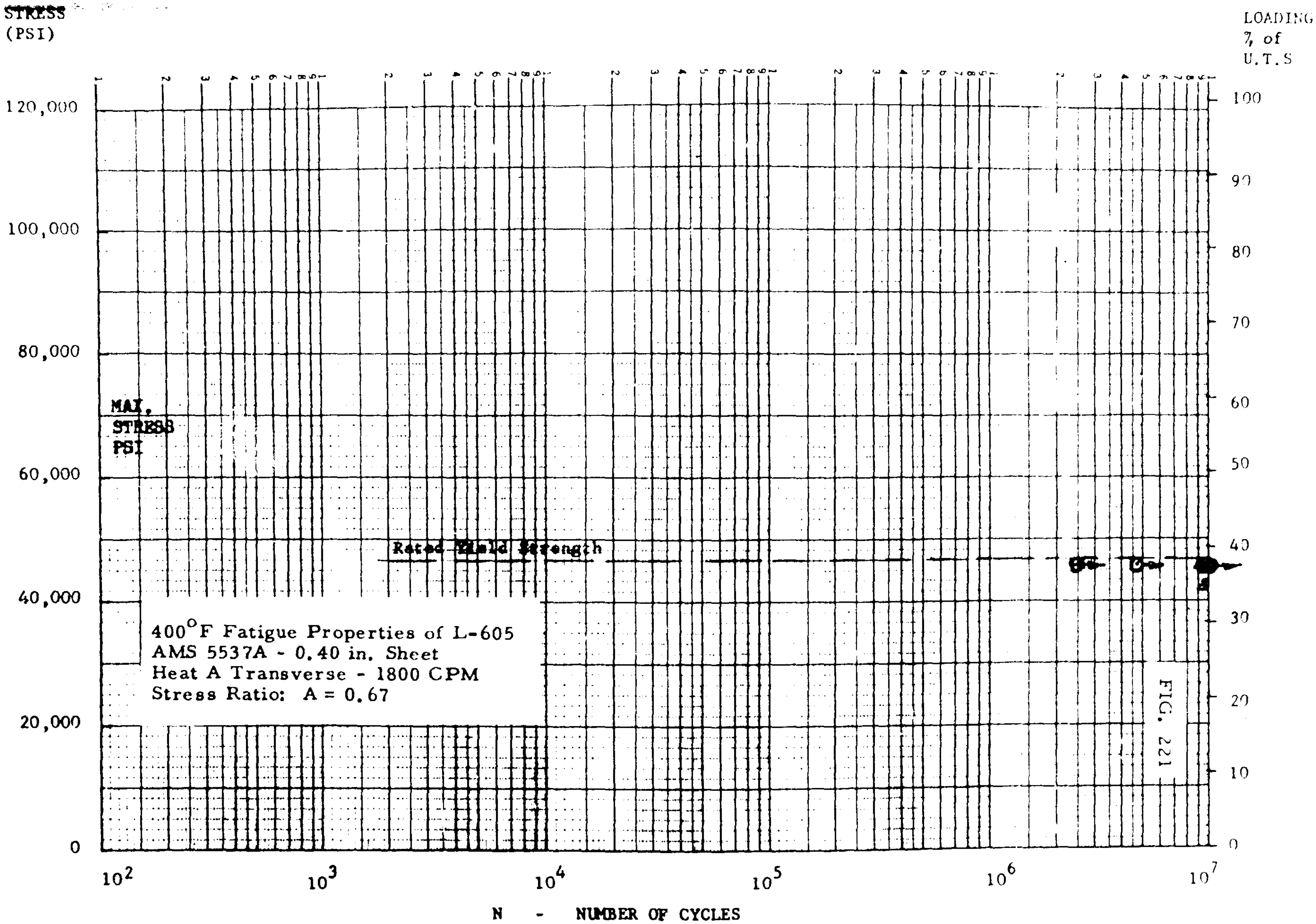
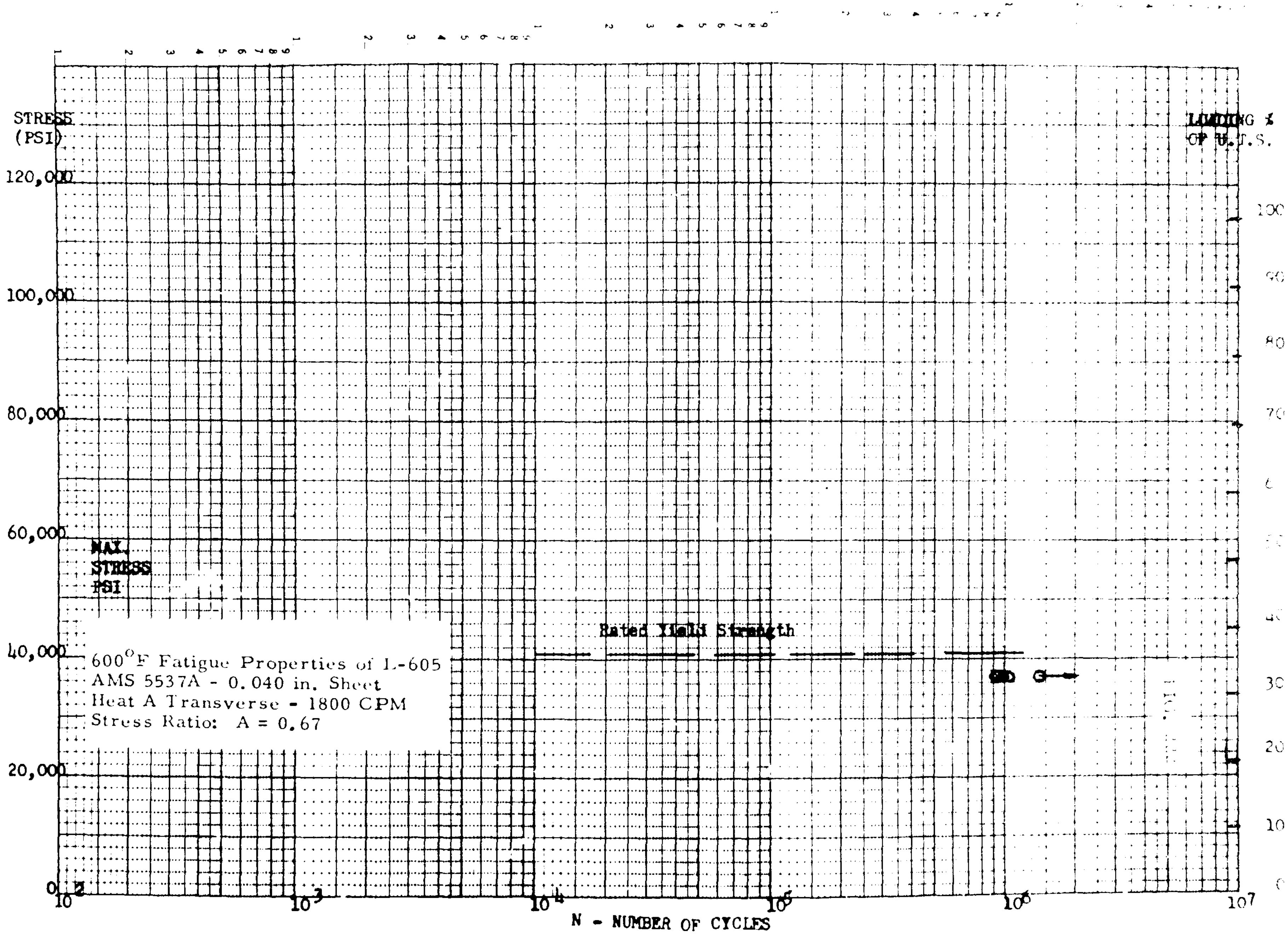
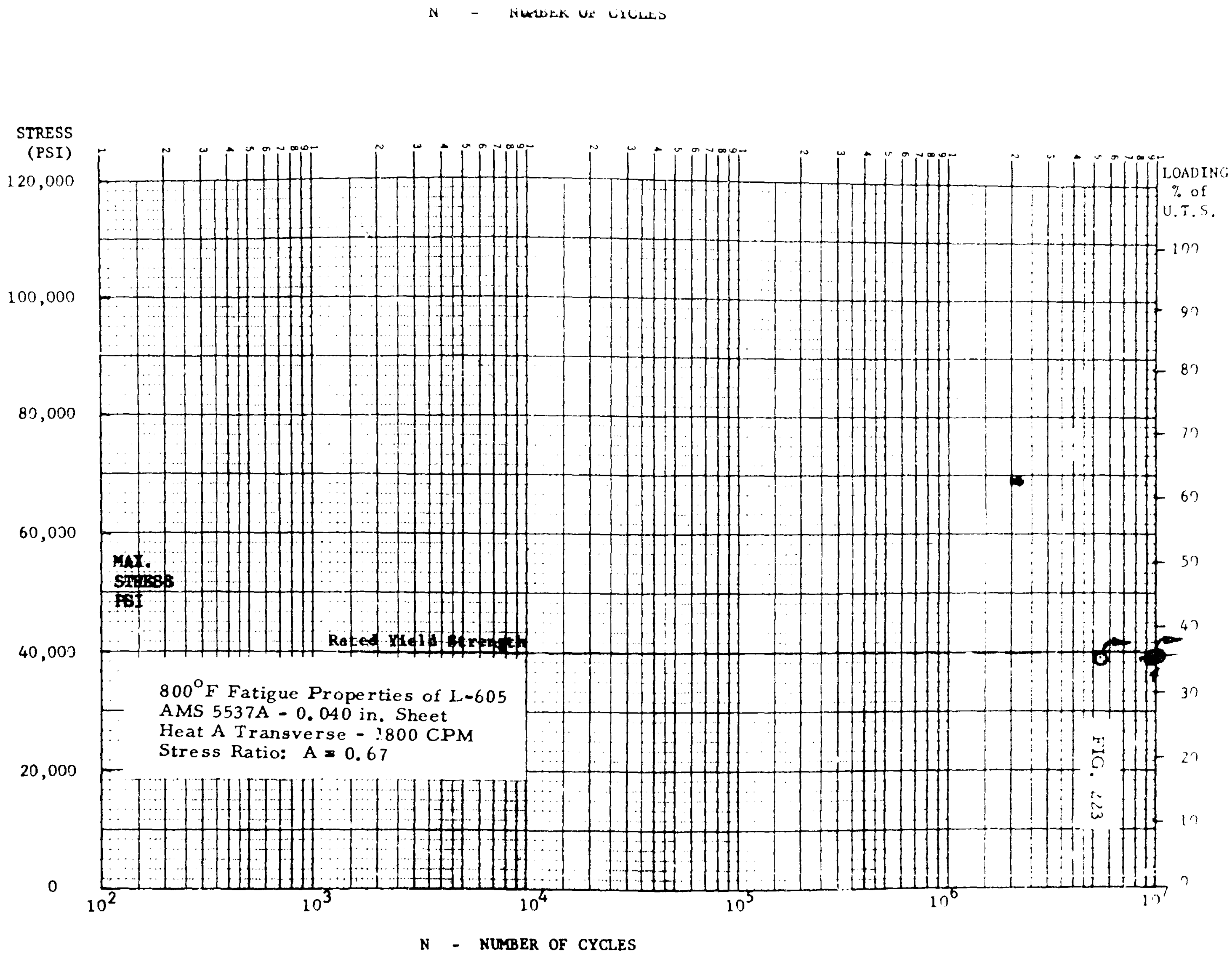

STRESS
(PSI)
LOADING
% of
U.T.S
120,000
100,000
80,000
60,000
40,000
20,000
0
100
90
80
70
60
50
40
30
20
10
0
MAX.
STRESS
PSI
Rated Yield Strength
400°F Fatigue Properties of L-605
AMS 5537A - 0.40 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 221



STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
MAX. STRESS PSI
Rated Yield Strength
LOADING % OF U.T.S.
100
90
80
70
30
20
10
N - NUMBER OF CYCLES
10^2
10^3
10^4
10^5
10^6
10^7
600°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67



N - NUMBER OF CYCLES
STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
MAX. STRESS PSI
Rated Yield Strength
800°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
N - NUMBER OF CYCLES

FIG. 223

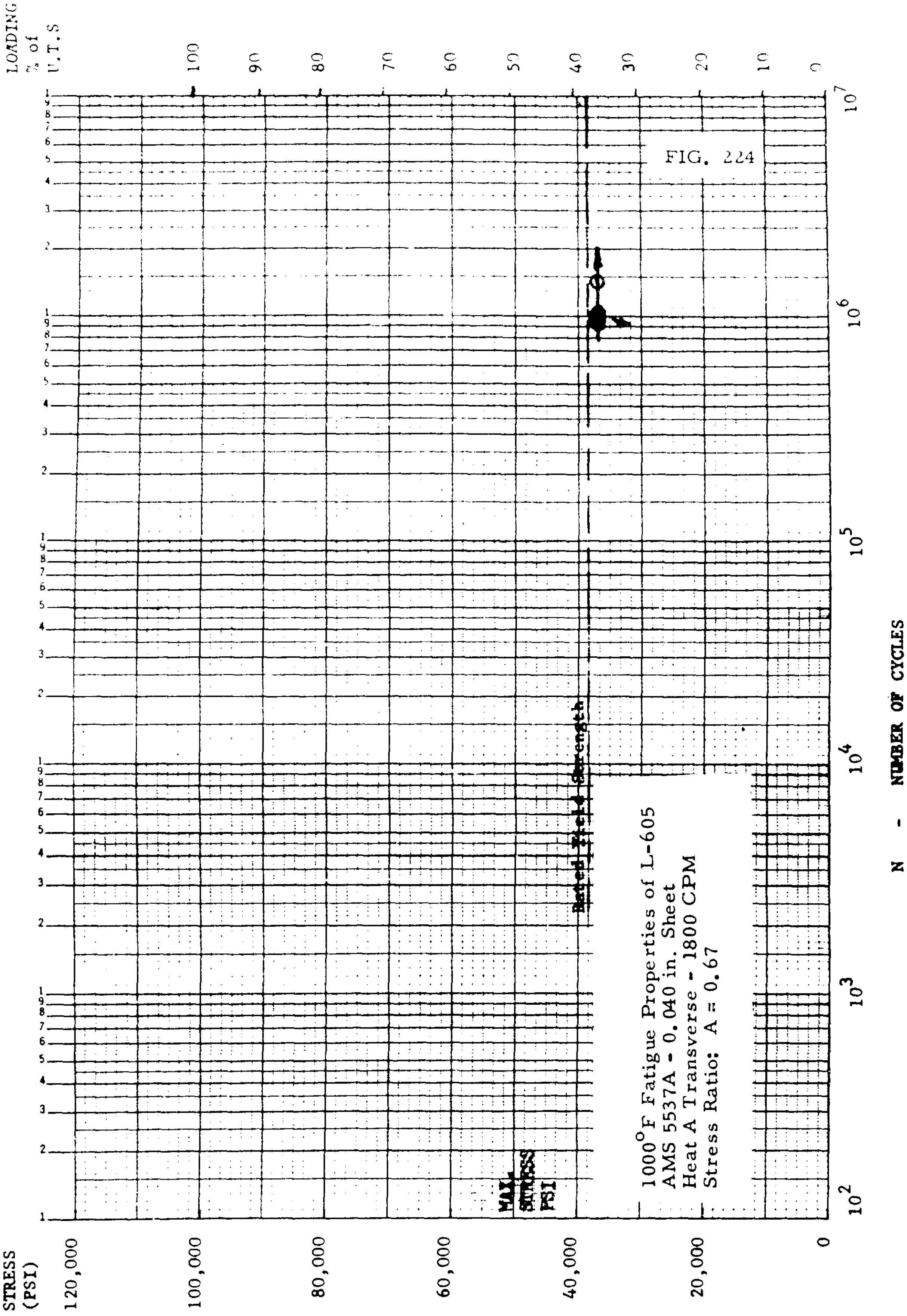


FIG. 224

1000°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67

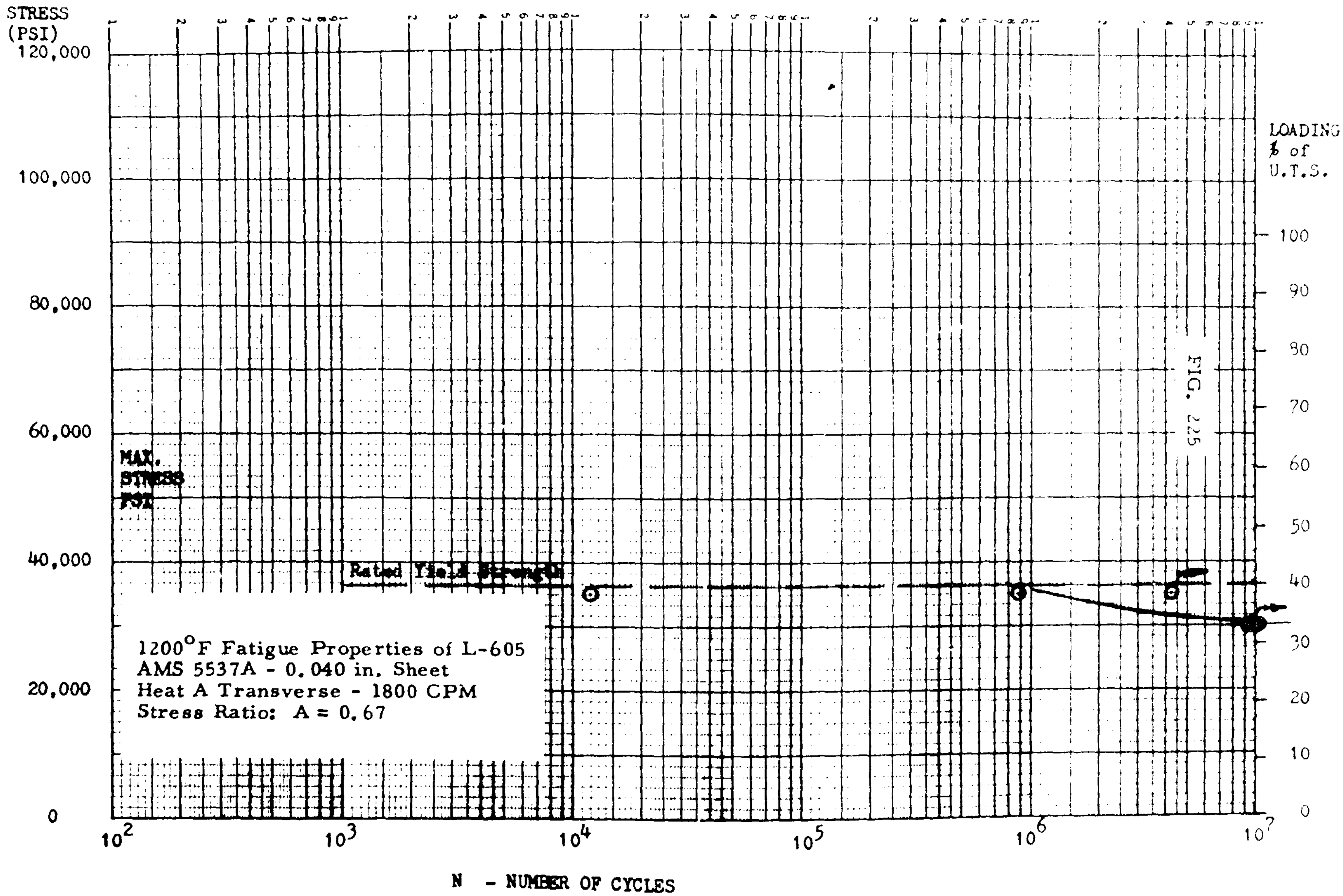


FIG. 225

1200°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67

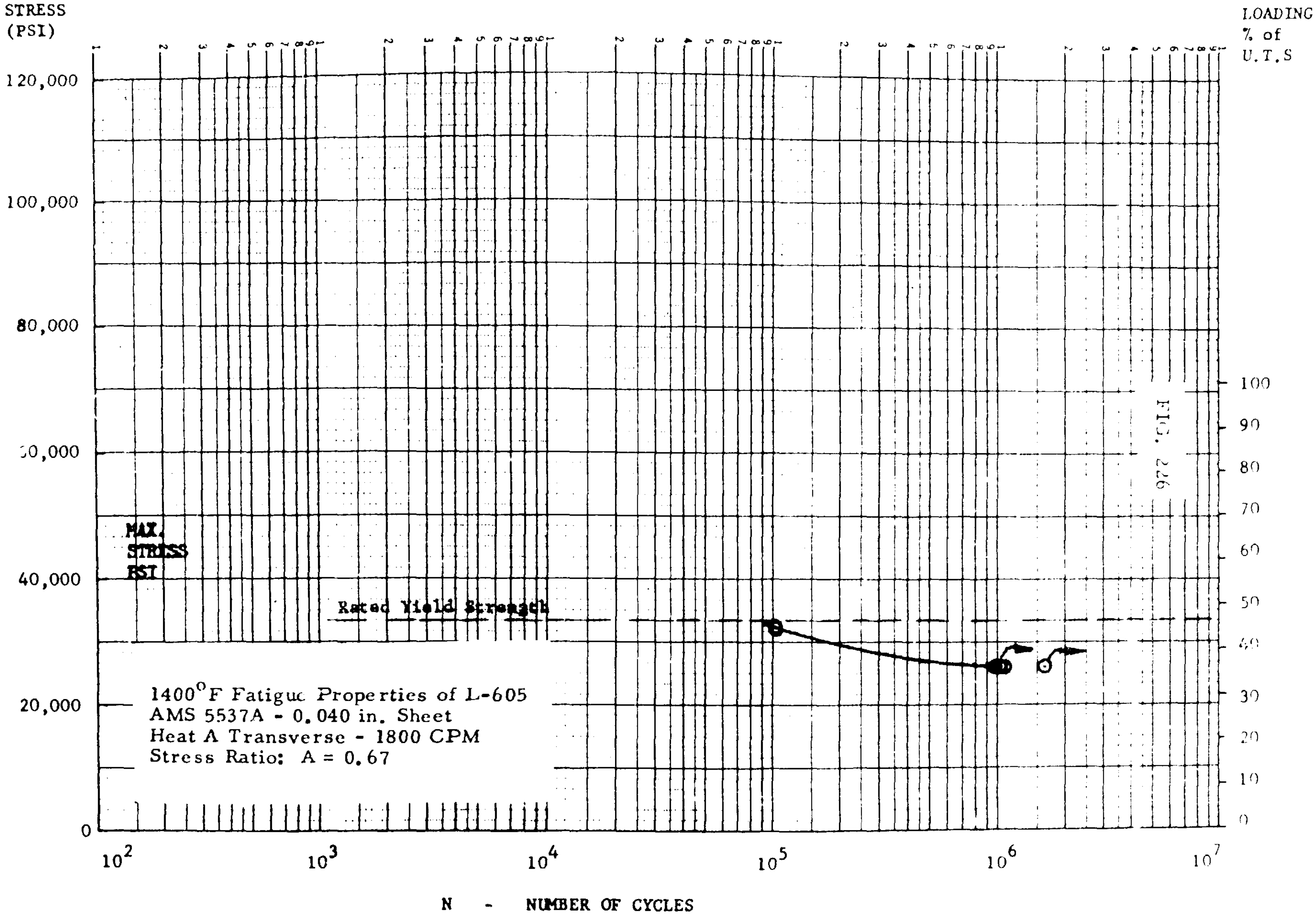
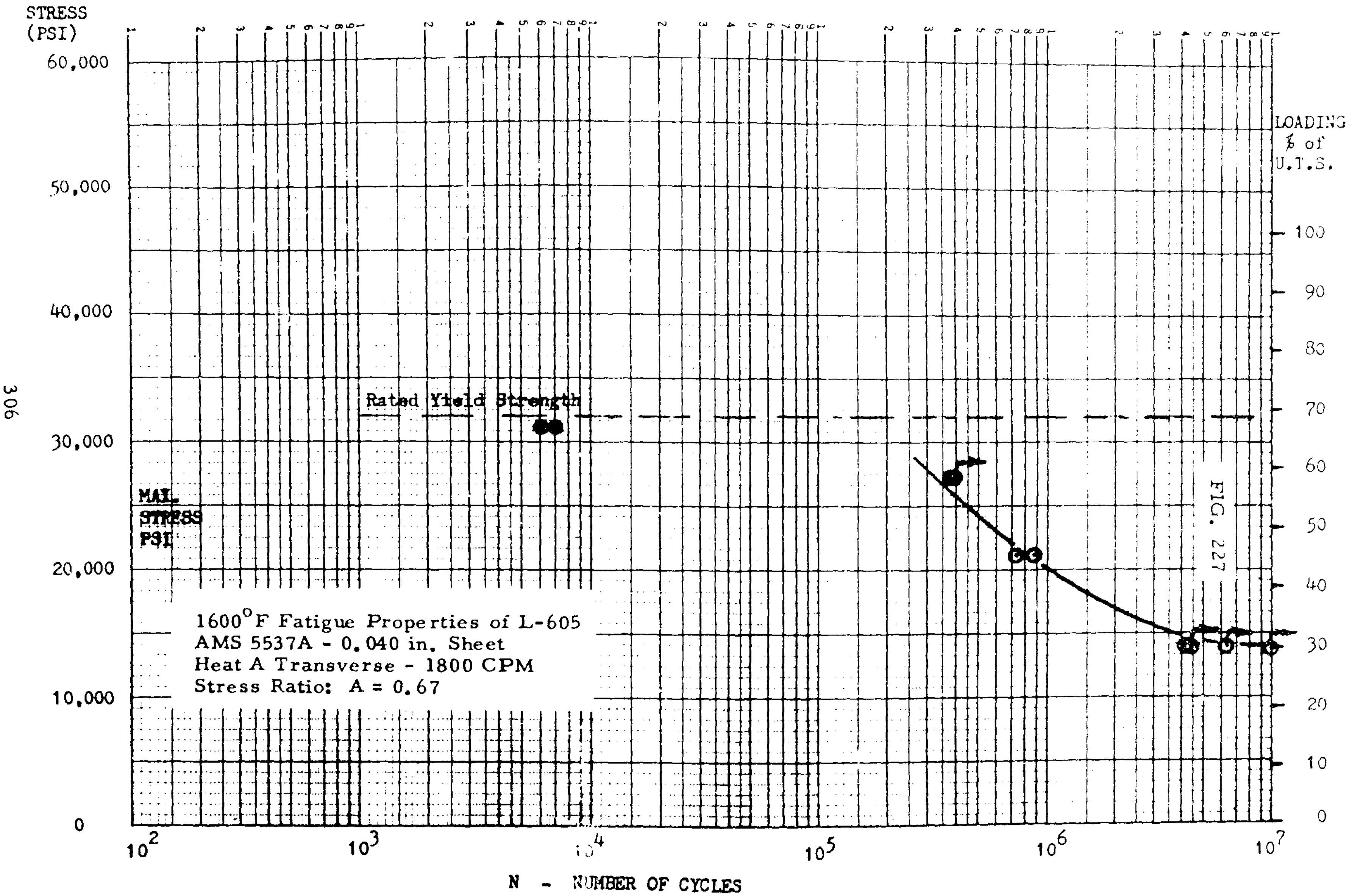

STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
LOADING % of U.T.S
100
90
80
70
60
50
40
30
20
10
0
MAX. STRESS PSI
Rated Yield Strength
1400°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 226


STRESS (PSI)
60,000
50,000
40,000
30,000
20,000
10,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
FIG. 227
1600°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
N - NUMBER OF CYCLES

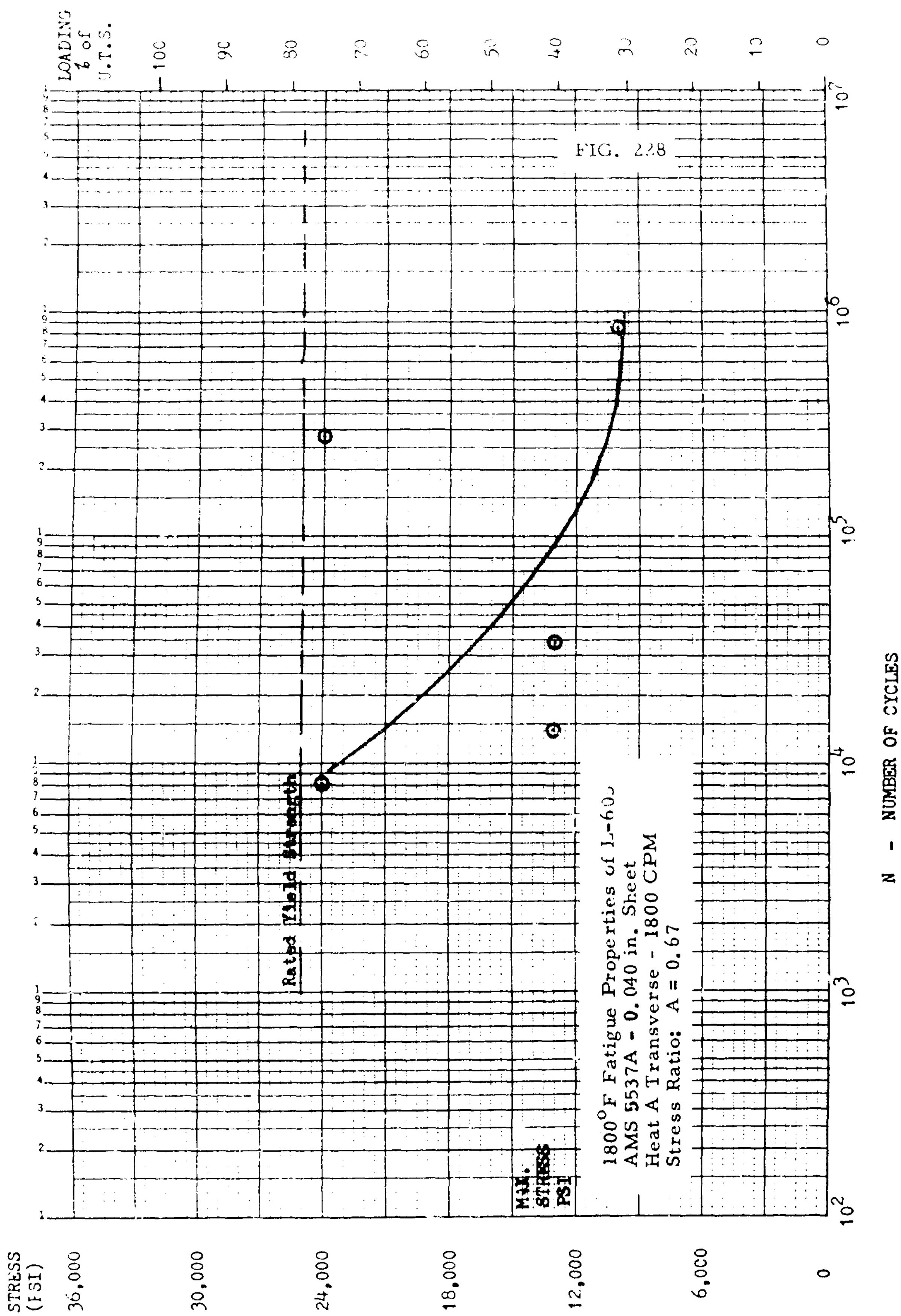
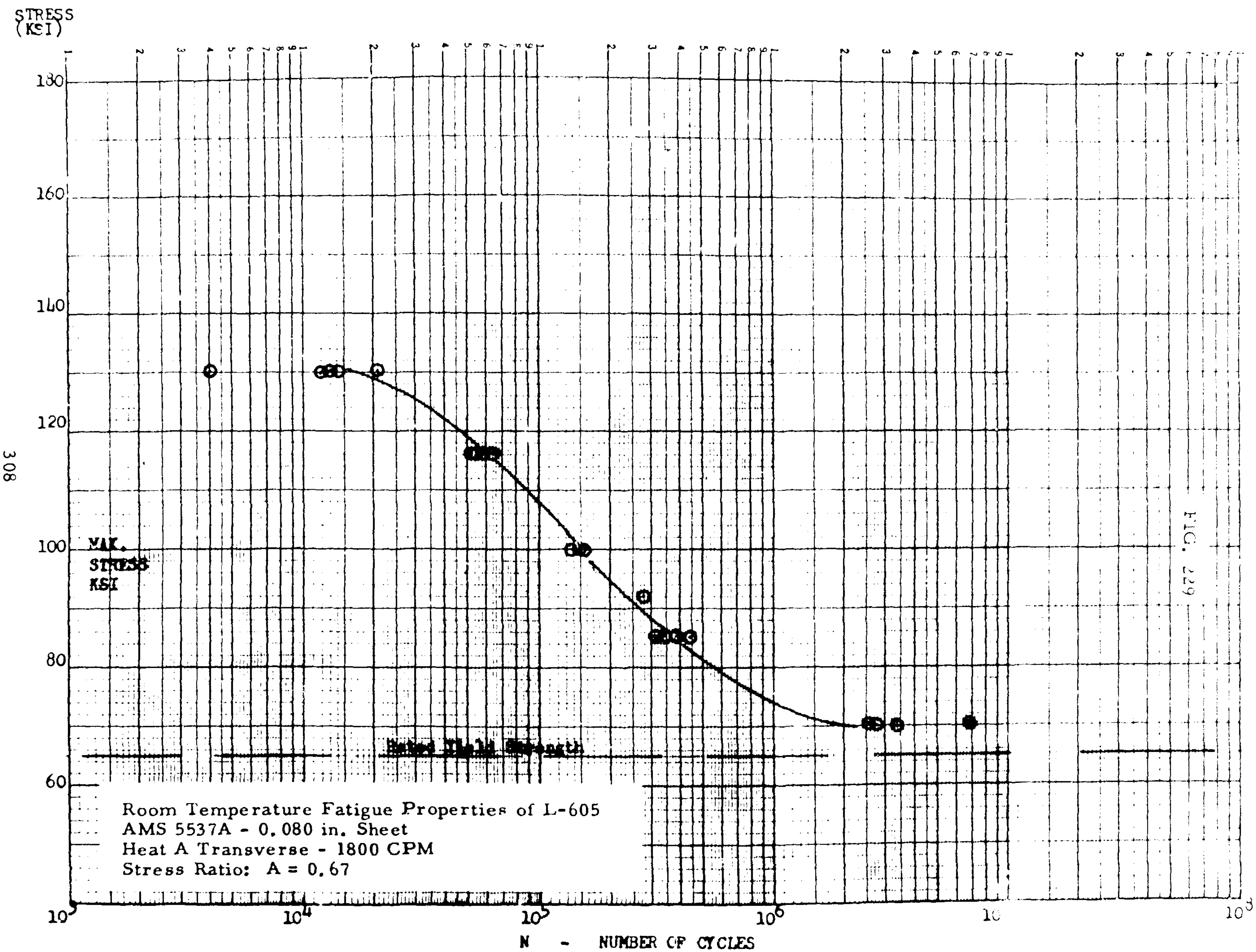
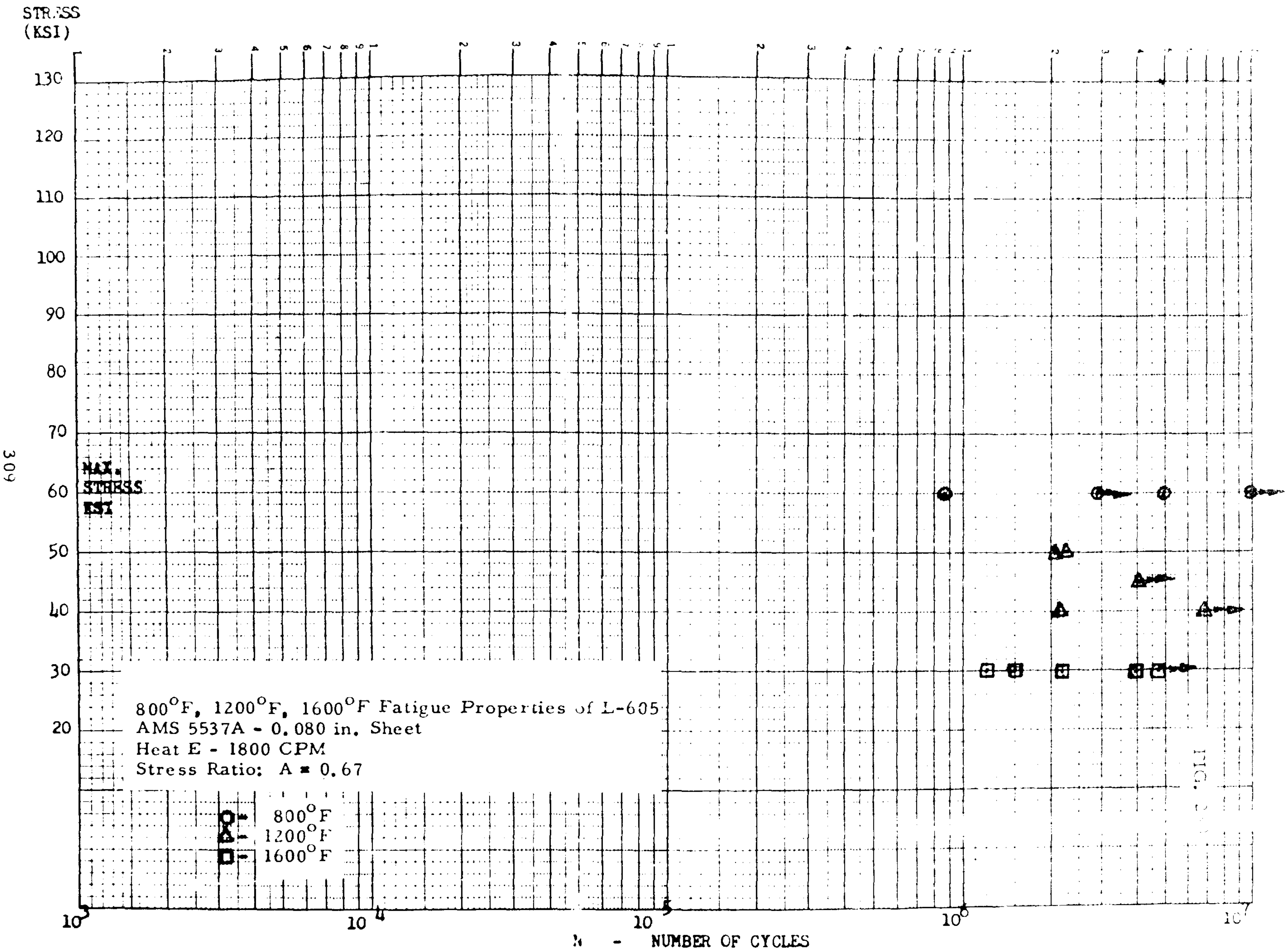

LOADING
% of
U.T.S.
100
90
80
70
60
50
40
30
20
10
0
STRESS
(PSI)
36,000
30,000
24,000
18,000
12,000
6,000
0
Rated Yield Strength
MAX.
STRESS
PSI
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES
1800°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67

FIG. 228

FIG. 229


STRESS (KSI)
180
160
140
120
100
80
60
MAX. STRESS KSI
Rated Yield Strength
Room Temperature Fatigue Properties of L-605
AMS 5537A - 0.080 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^3
10^4
10^5
10^6
10^8
N - NUMBER OF CYCLES


STRESS (KSI)
MAX. STRESS KSI
800°F, 1200°F, 1600°F Fatigue Properties of L-605
AMS 5537A - 0.080 in. Sheet
Heat E - 1800 CPM
Stress Ratio: A = 0.67
800°F
1200°F
1600°F
N - NUMBER OF CYCLES

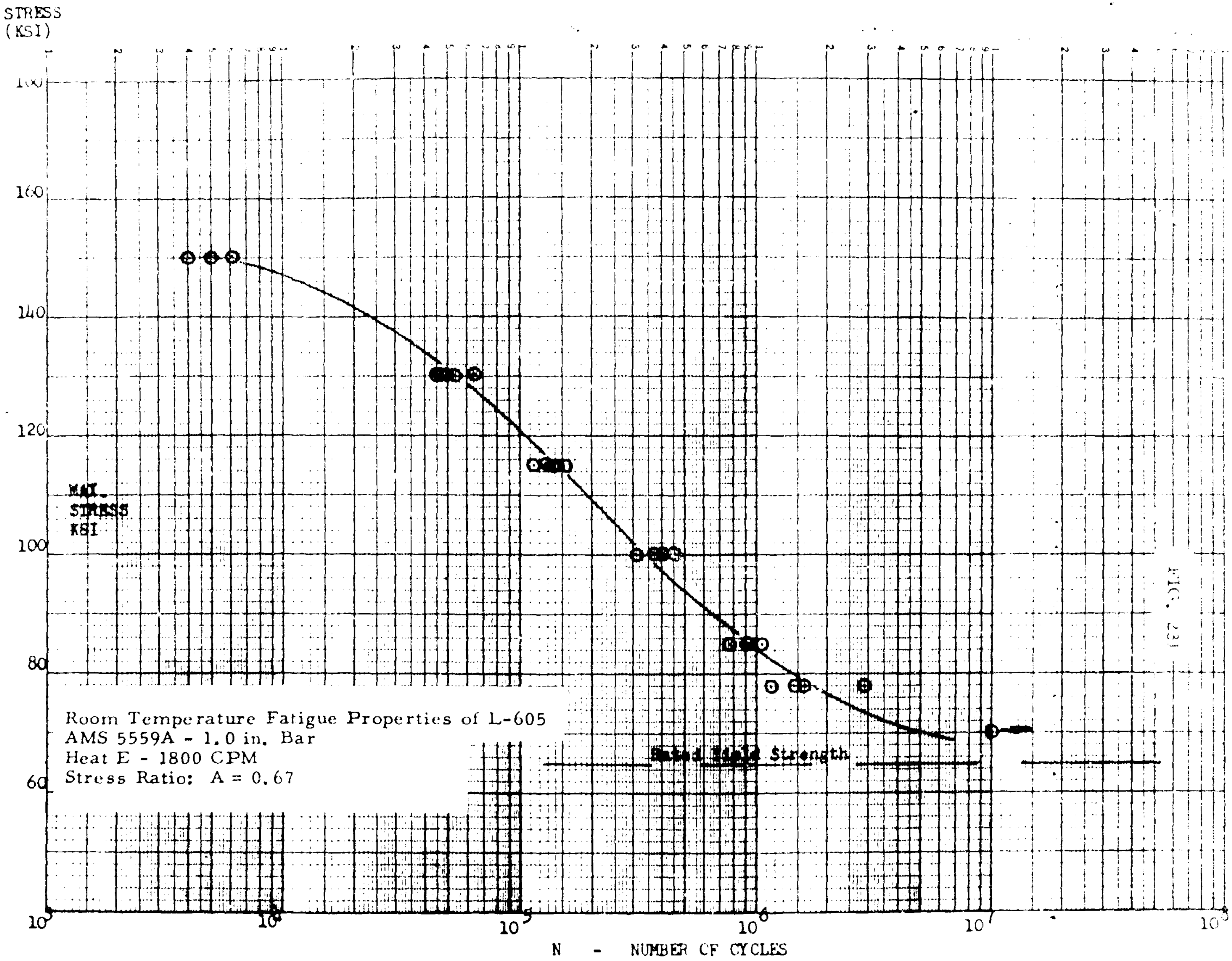
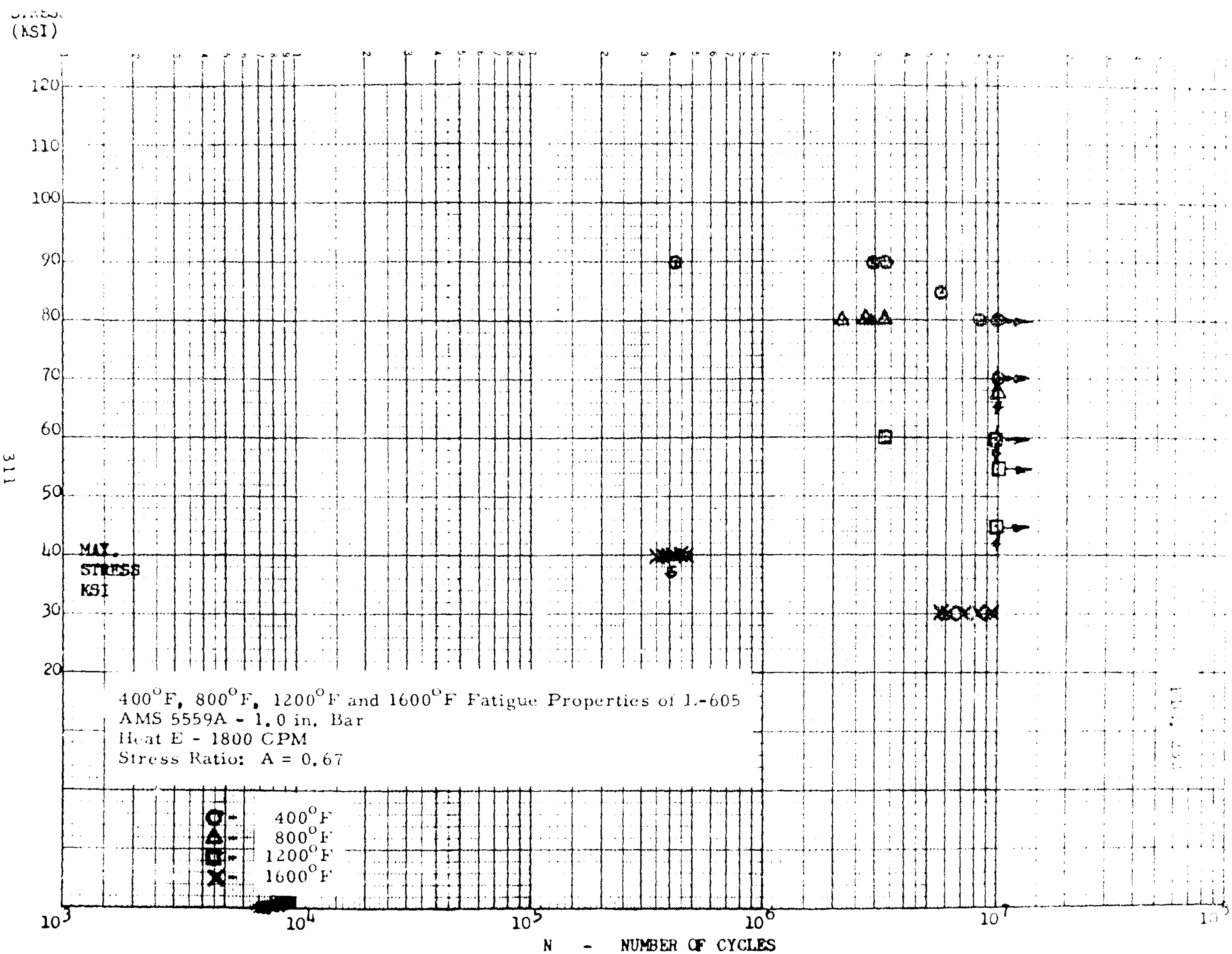
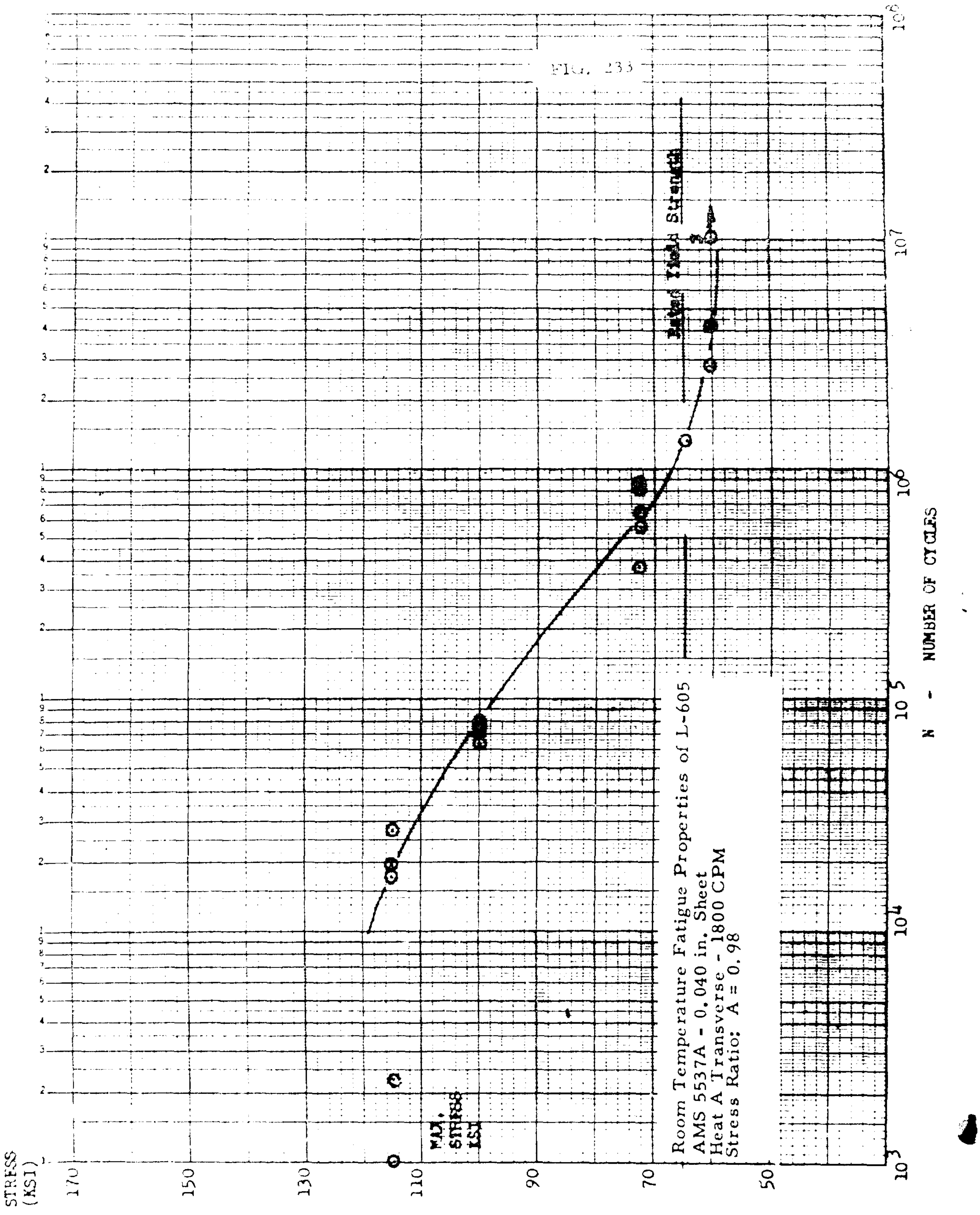

STRESS (KSI)
MAX. STRESS KSI
Room Temperature Fatigue Properties of L-605
AMS 5559A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.67
Rated Yield Strength
N - NUMBER OF CYCLES

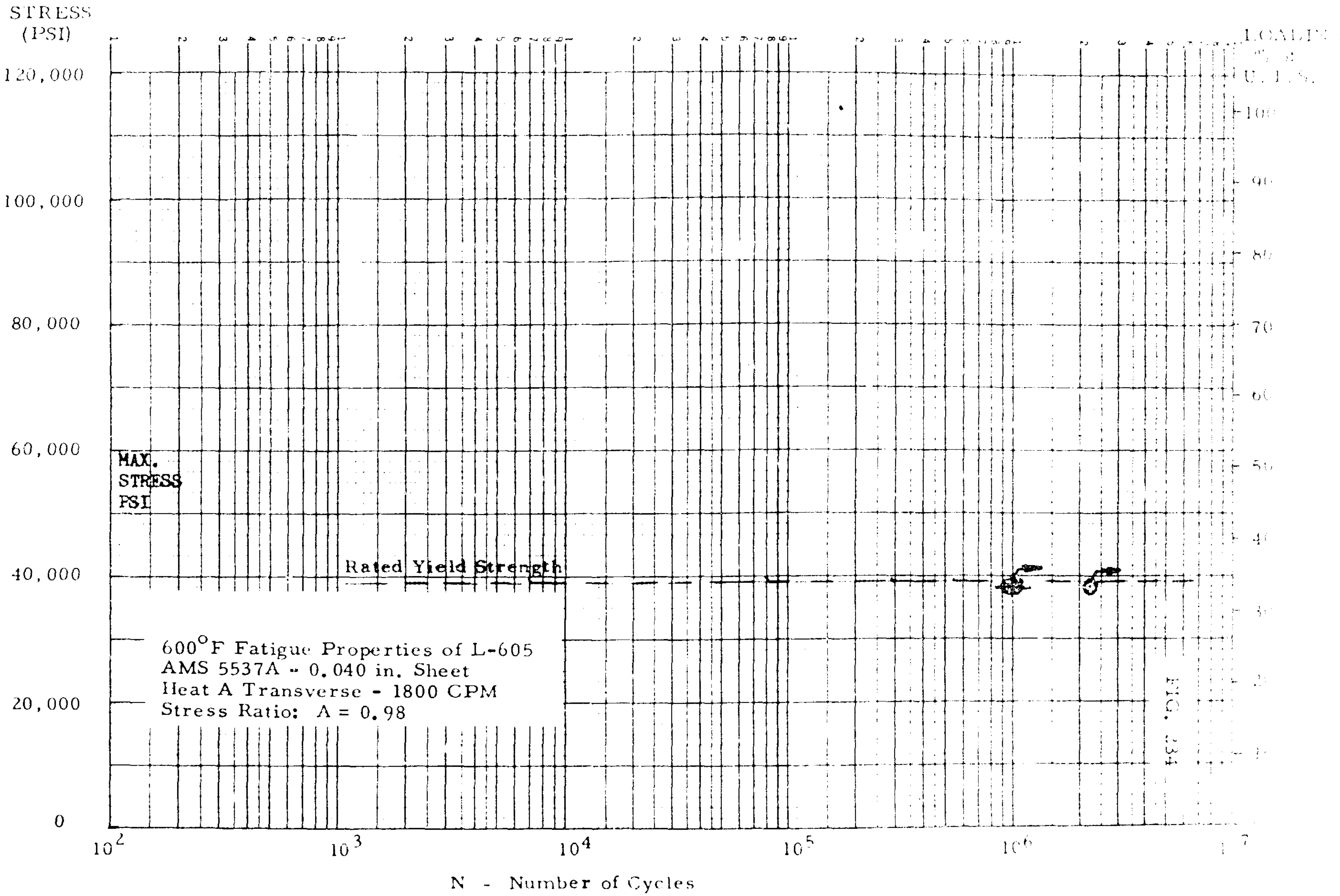
FIG. 231



400°F, 800°F, 1200°F and 1600°F Fatigue Properties of L-605
AMS 5559A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.67



Room Temperature Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98


STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
MAX. STRESS PSI
Rated Yield Strength
600°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
10^2
10^3
10^4
10^5
10^6
N - Number of Cycles
FIG. 234

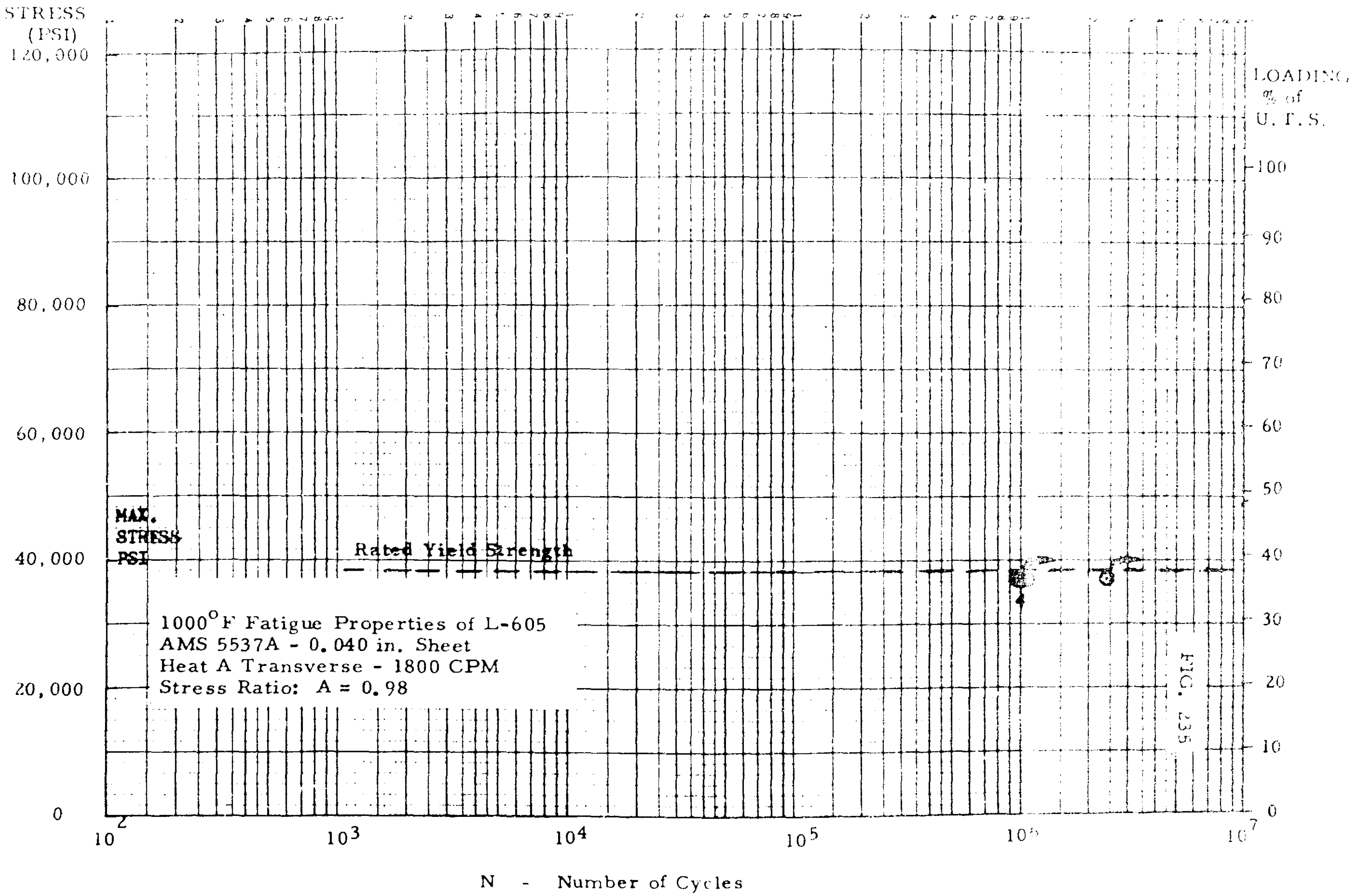
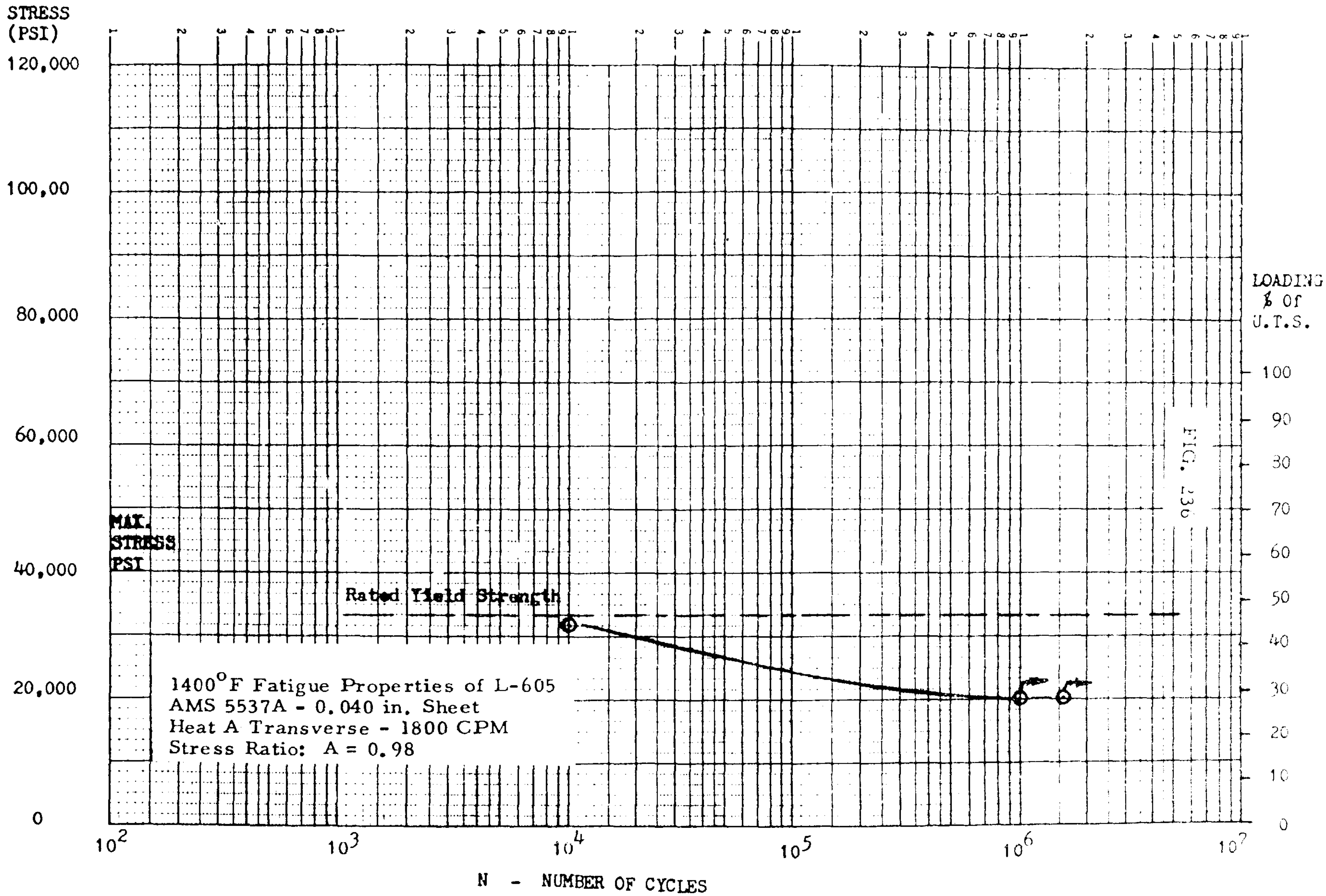
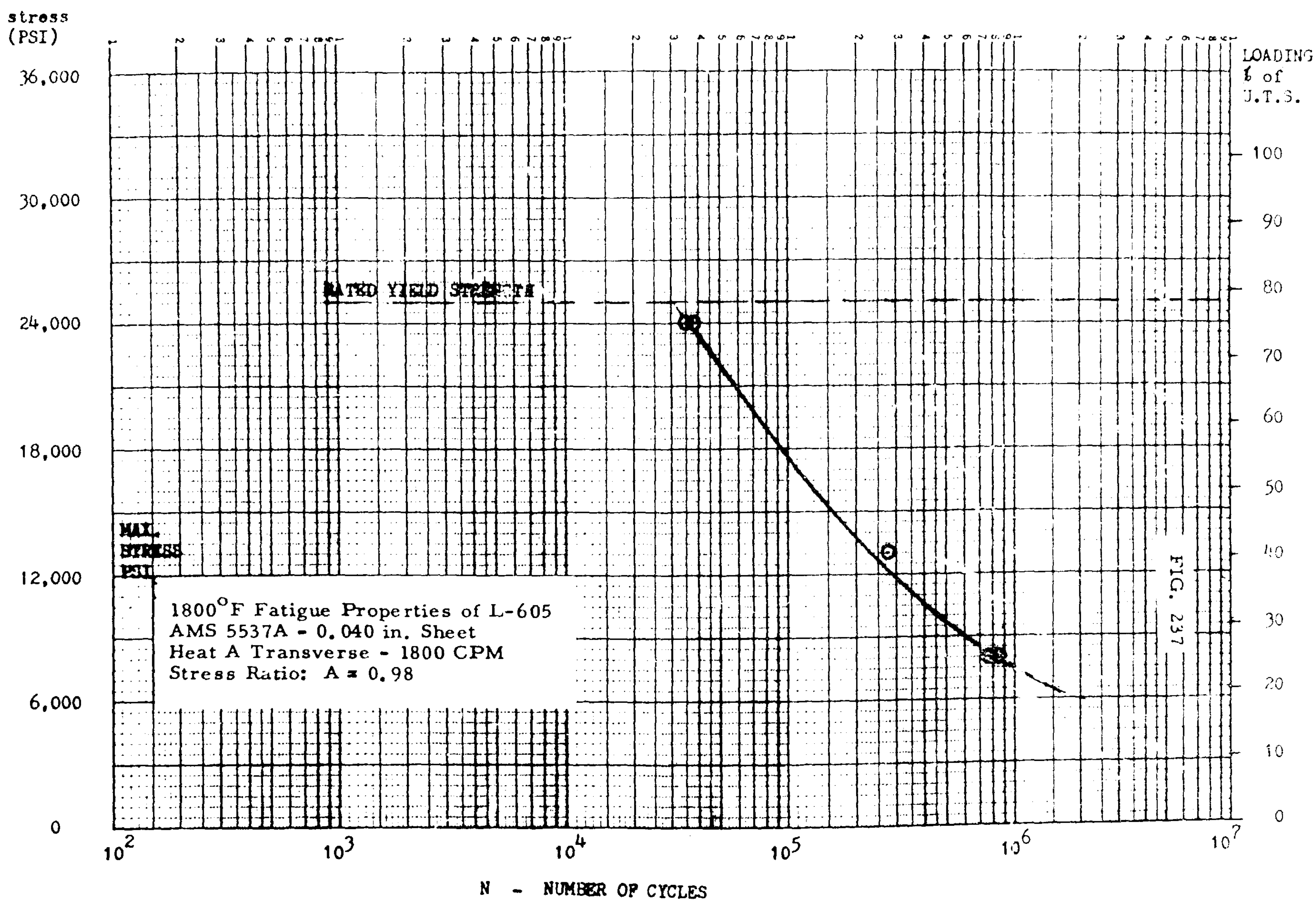

STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
MAX. STRESS PSI
Rated Yield Strength
1000°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
LOADING, % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
10^2
10^3
10^4
10^5
10^6
10^7
N - Number of Cycles

FIG. 235

FIG. 236



STRESS (PSI)
120,000
100,00
80,000
60,000
40,000
20,000
0
MAX. STRESS PSI
Rated Yield Strength
1400°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES



stress (PSI)
36,000
30,000
24,000
18,000
12,000
6,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
RATED YIELD STRENGTH
MAX. STRESS PSI
1800°F Fatigue Properties of L-605
AMS 5537A - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 237

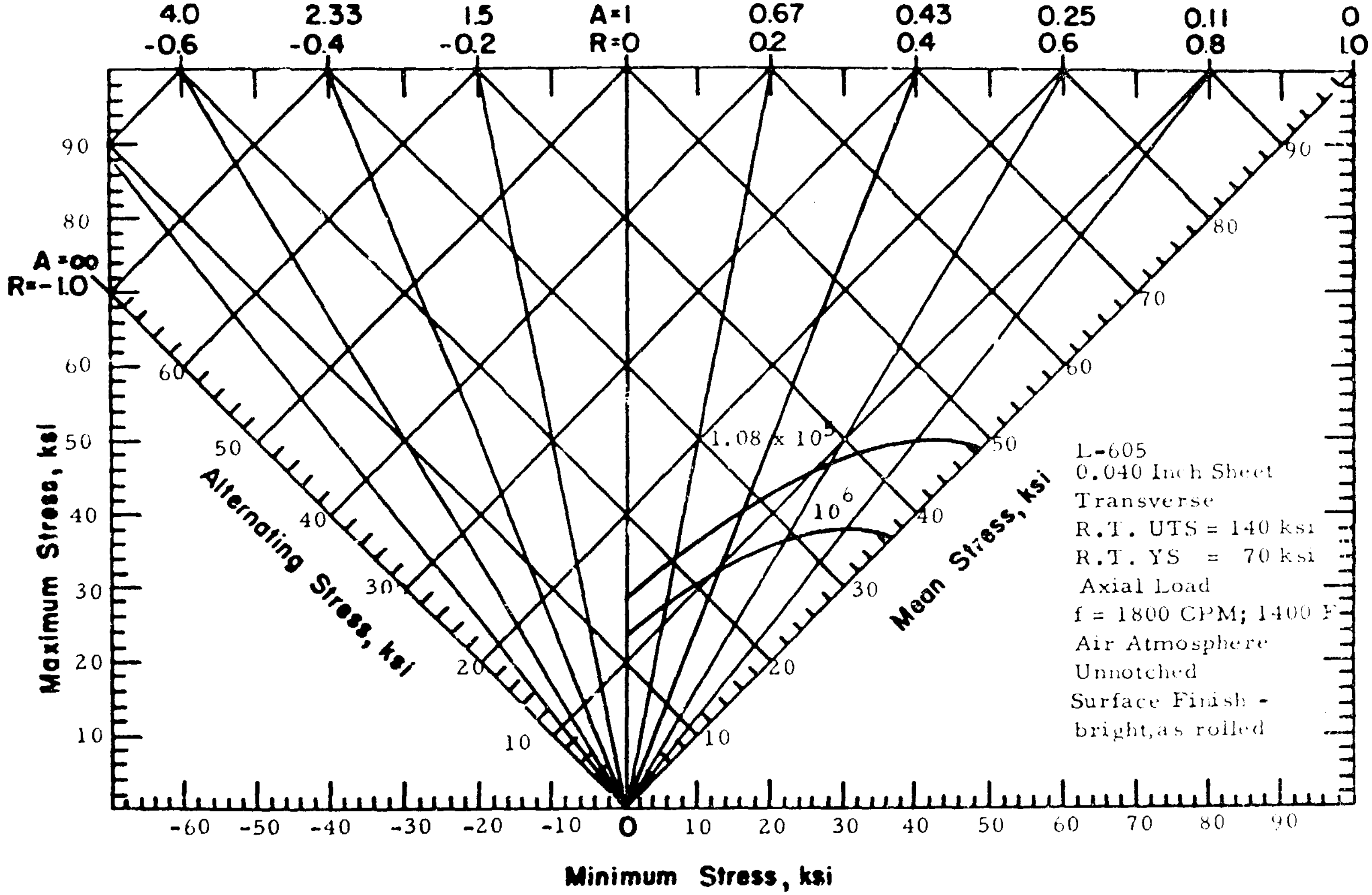


FIGURE
TYPICAL CONSTANT LIFE DIAGRAM FOR FATIGUE BEHAVIOR OF L-605
SHEET MATERIAL AT 1400 F.

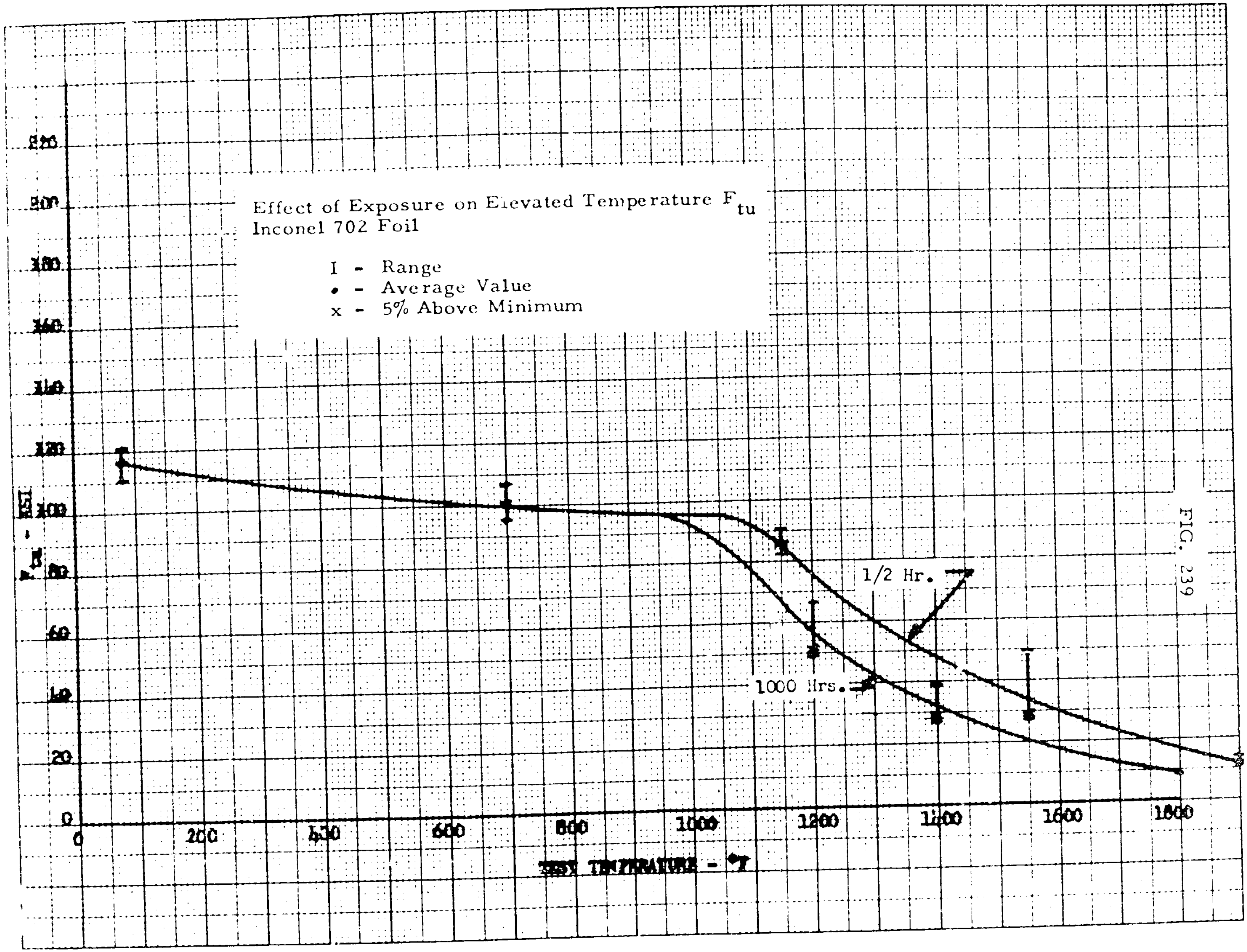
SECTION VII - TEST RESULTS, TABLES AND GRAPHS

SECTION 7.3 MATERIAL, INCONEL 702

TABLE OF CONTENTS

SECTION VII

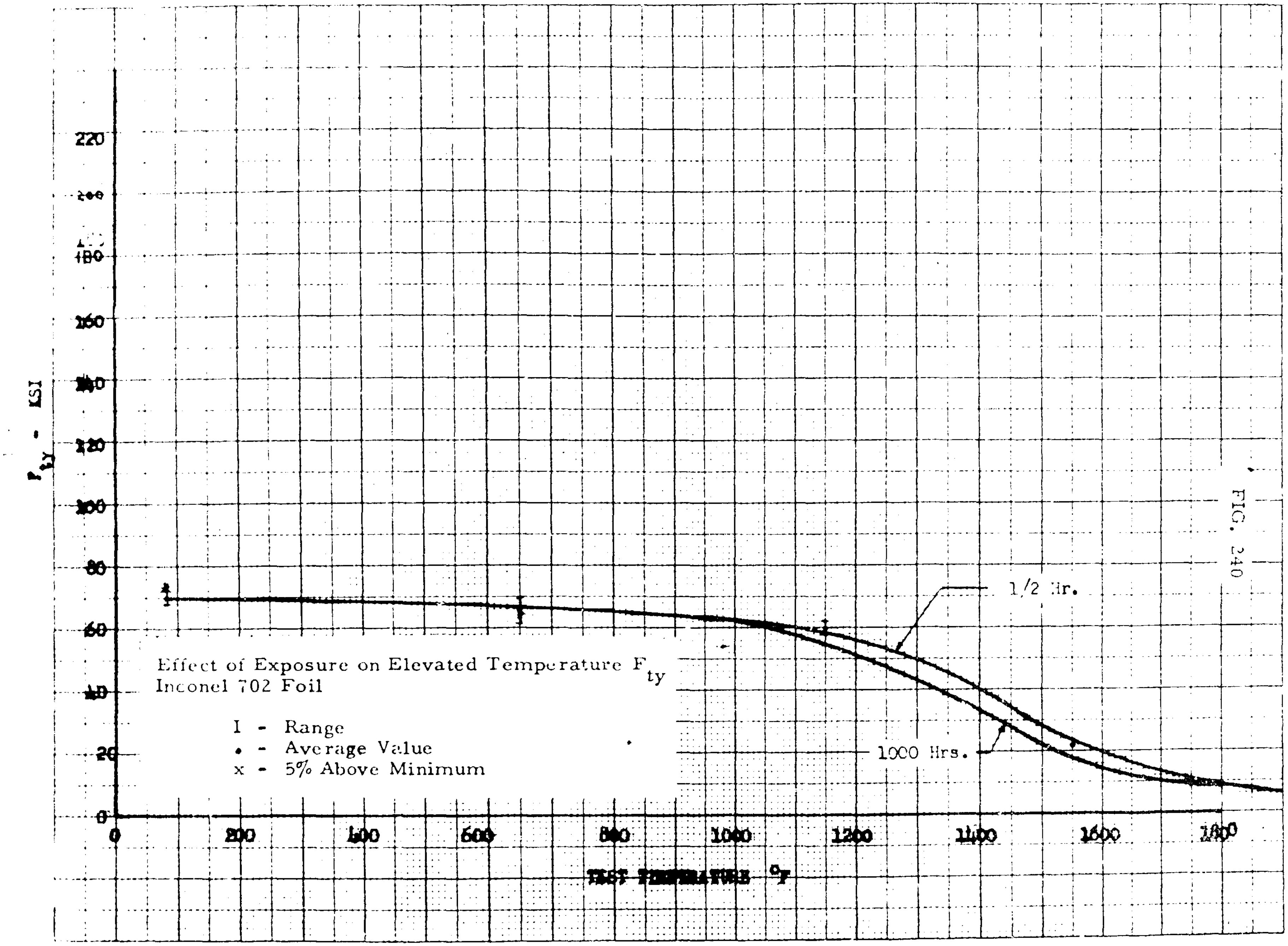
Section 7.3.1 Tension



Effect of Exposure on Elevated Temperature F_{tu}
Inconel 702 Foil
I - Range
• - Average Value
x - 5% Above Minimum
1/2 Hr.
1000 Hrs.
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE - °F

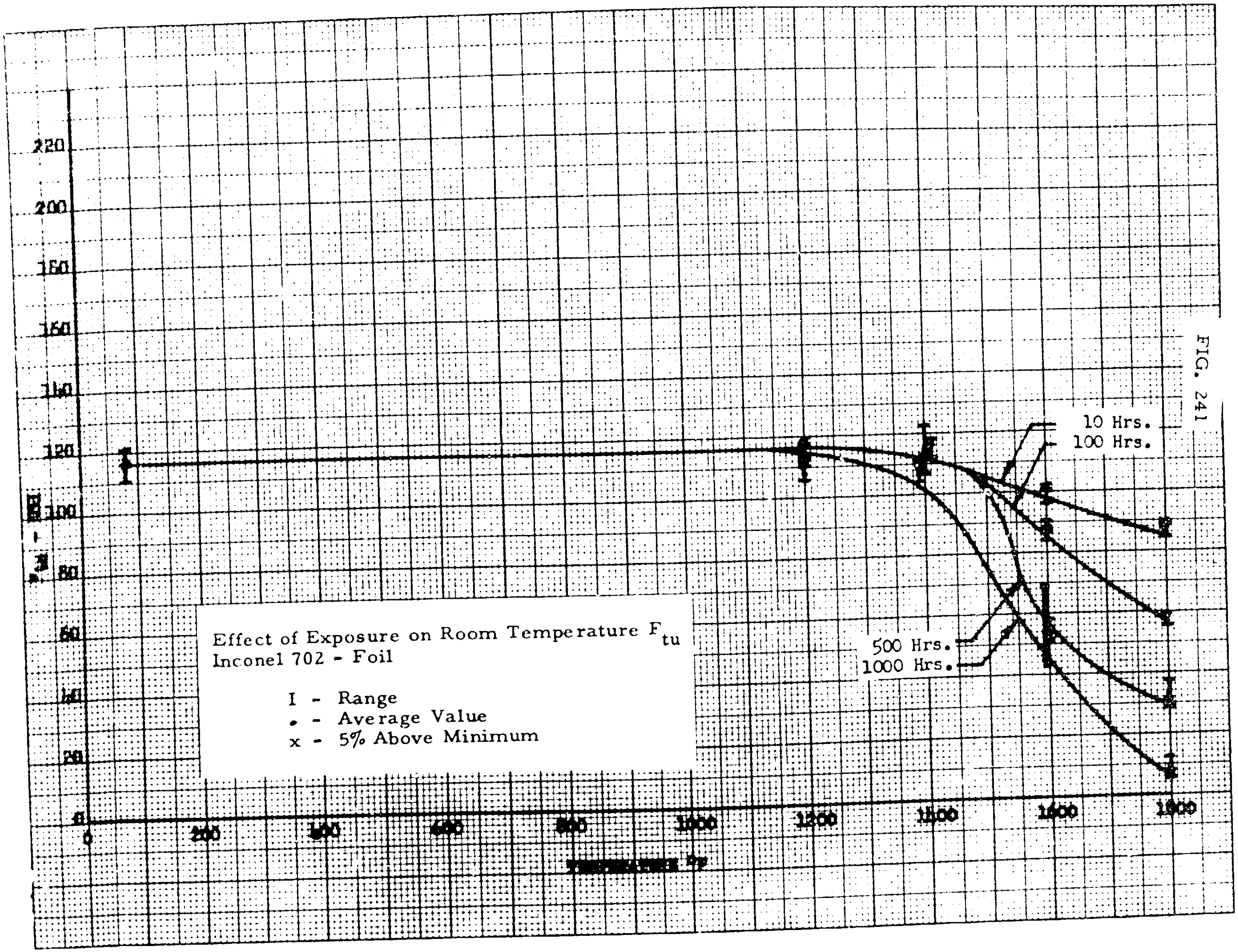
FIG. 239

FIG. 240



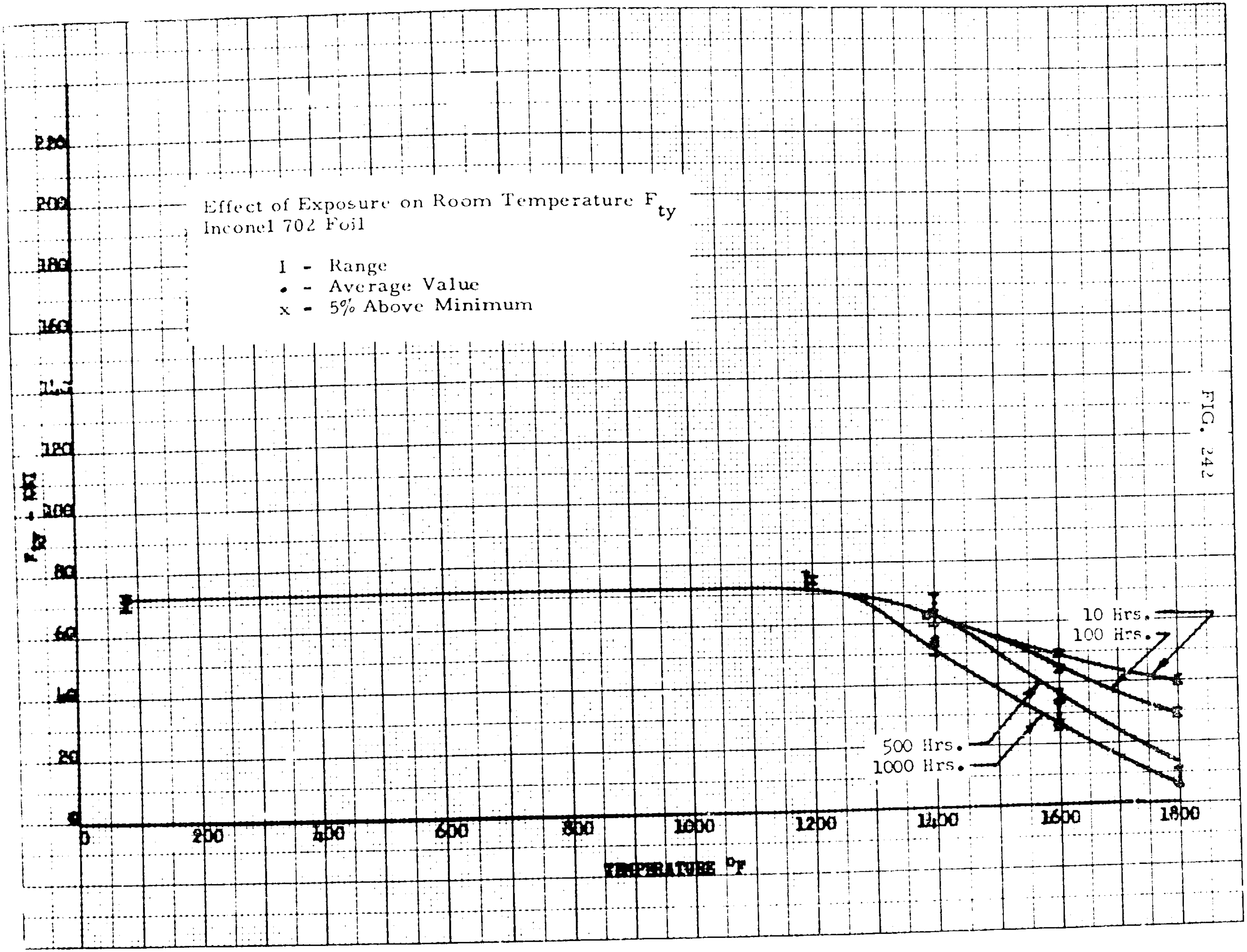
Effect of Exposure on Elevated Temperature F_{ty}
Inconel 702 Foil
I - Range
• - Average Value
x - 5% Above Minimum
1/2 Hr.
1000 Hrs.
F_{ty} - KSI
TEST TEMPERATURE °F
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 241



Effect of Exposure on Room Temperature F_{tu}
Inconel 702 - Foil
I - Range
• - Average Value
x - 5% Above Minimum
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
220
200
120
100
80
60
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 242


Effect of Exposure on Room Temperature F_{ty}
Inconel 702 Foil
I - Range
• - Average Value
x - 5% Above Minimum
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
0
200
400
600
800
1000
1200
1400
1600
1800
20
60
80
100
120
160
180
200
TEMPERATURE °F

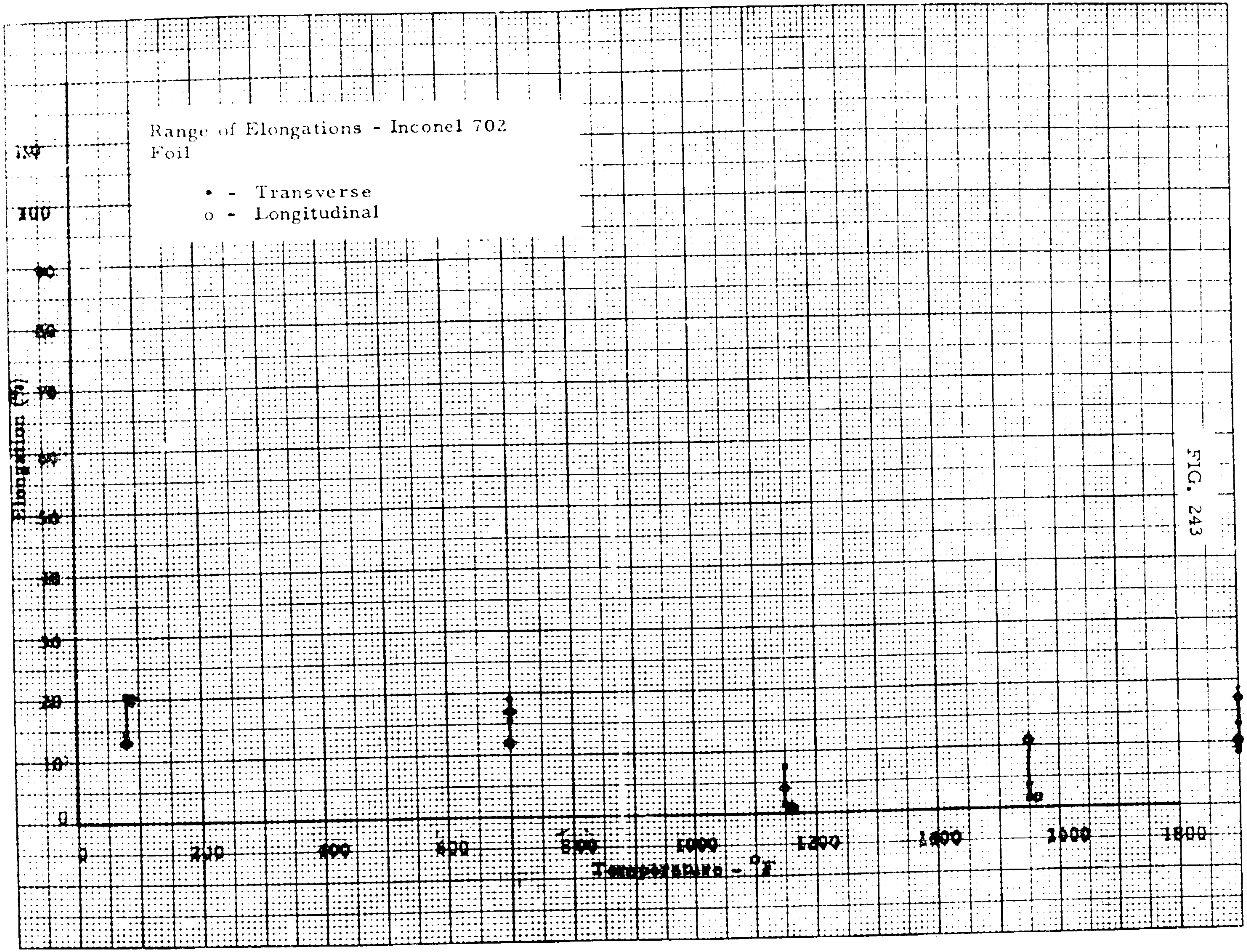

Range of Elongations - Inconel 702
Foil
• - Transverse
o - Longitudinal
Elongation (%)
Temperature - °F
0
200
400
600
800
1000
1200
1400
1600
1800
10
20
30
40
50
60
70
80
90
100

FIG. 243

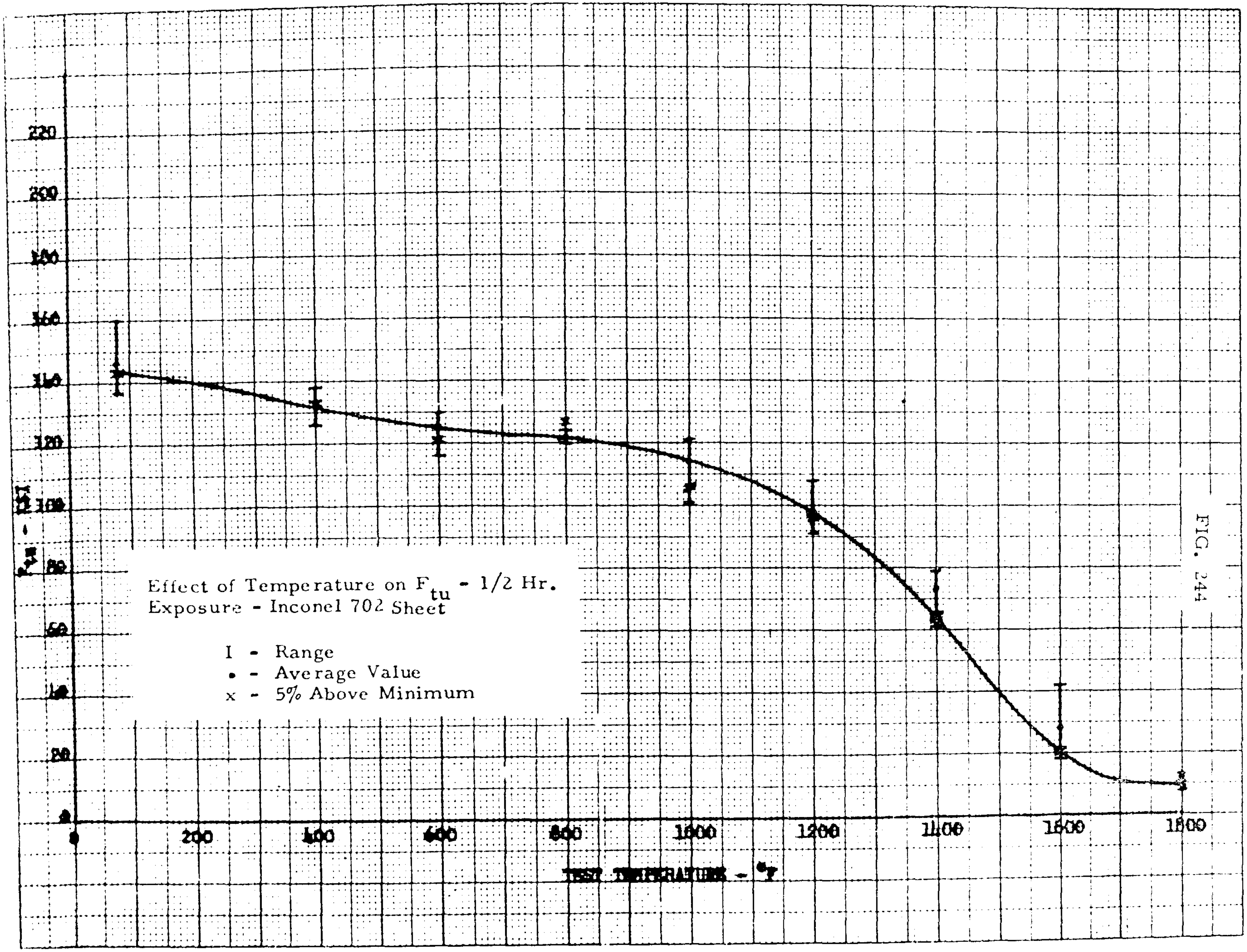
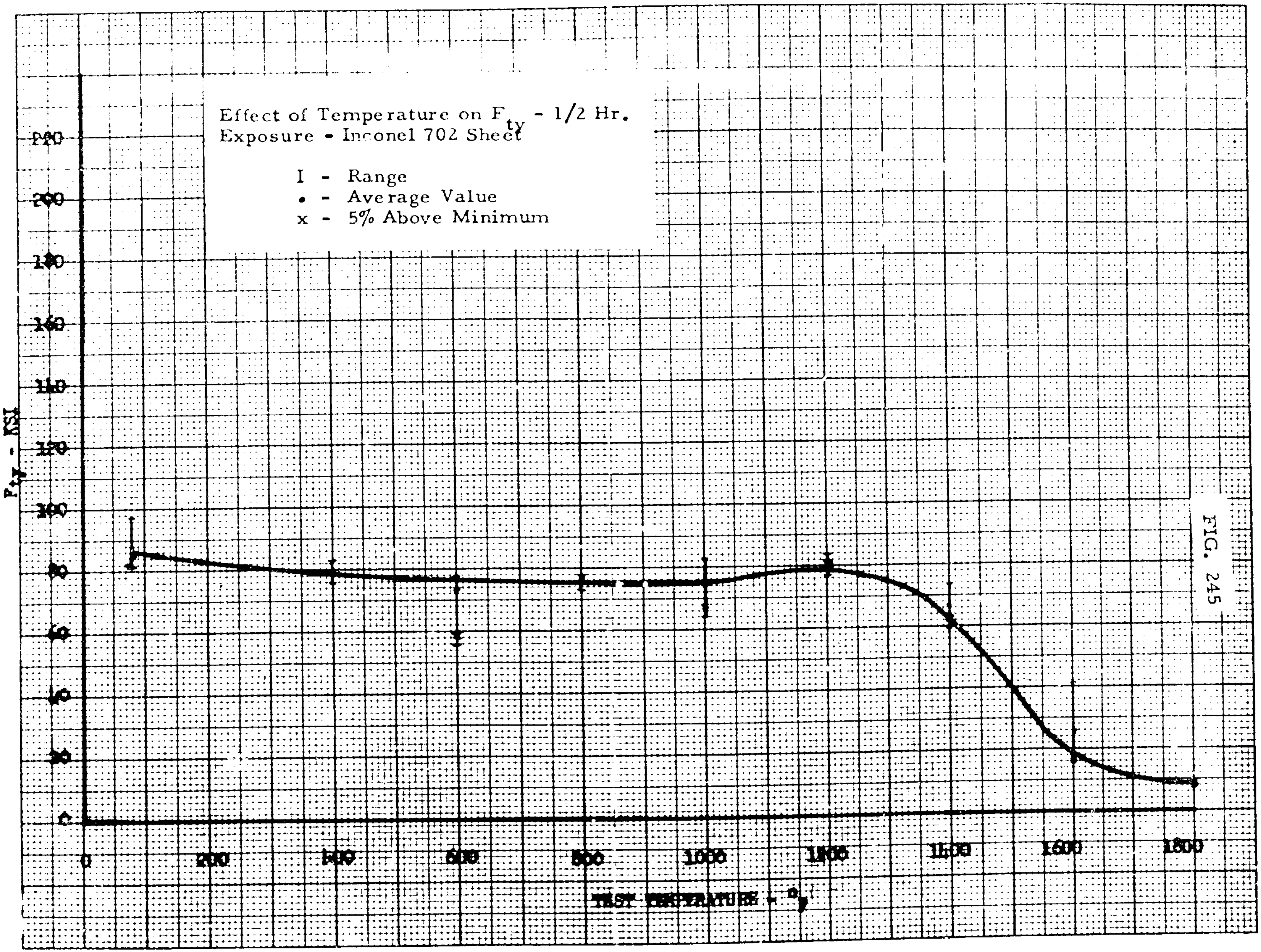

Effect of Temperature on F_{tu} - 1/2 Hr.
Exposure - Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE - °F

FIG. 244

FIG. 245



Effect of Temperature on F_{ty} - 1/2 Hr.
Exposure - Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
F_{ty} - KSI
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE - °F

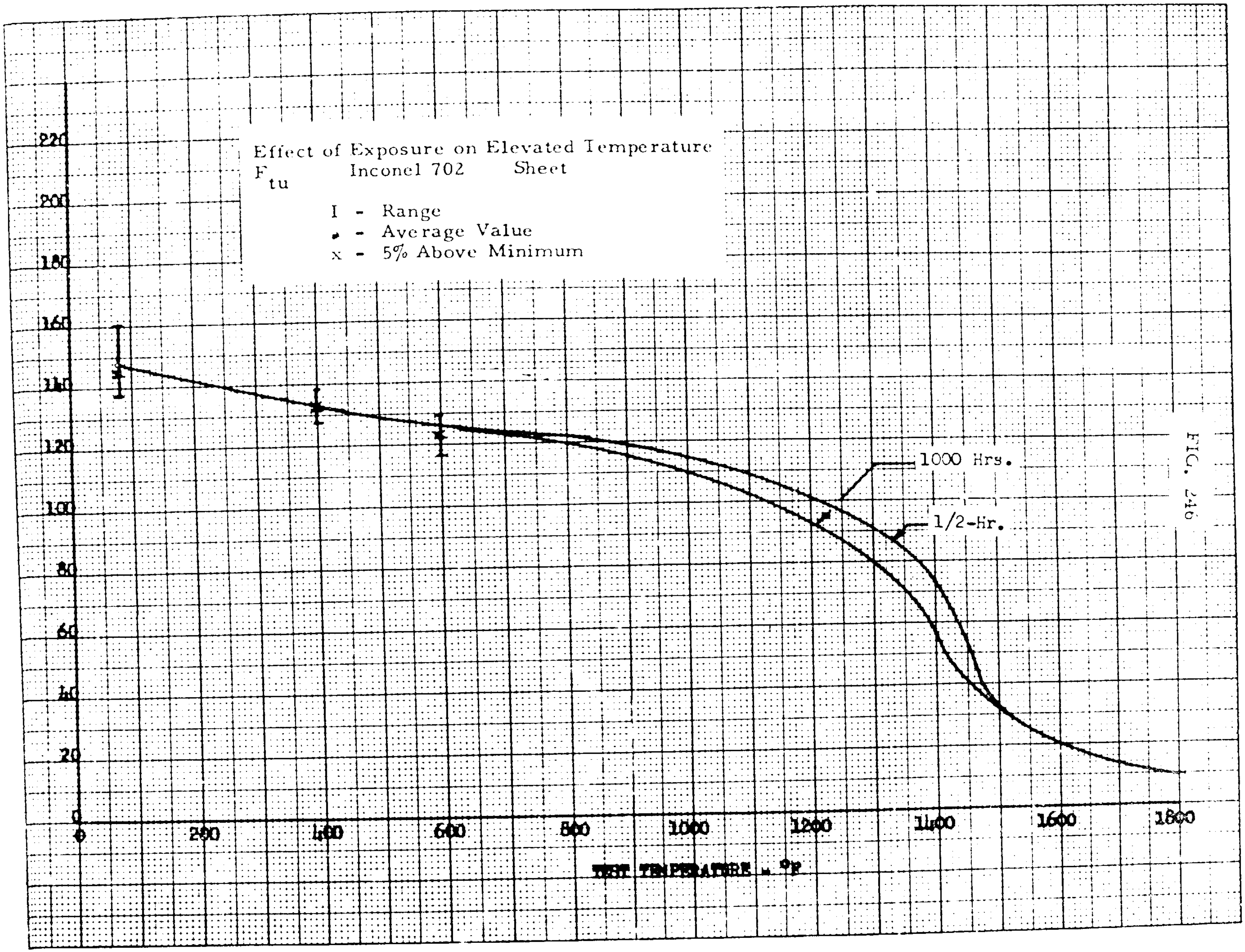


FIG. 246
Effect of Exposure on Elevated Temperature
F_{tu} Inconel 702 Sheet
I - Range
- Average Value
x - 5% Above Minimum
1000 Hrs.
1/2-Hr.
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE - °F

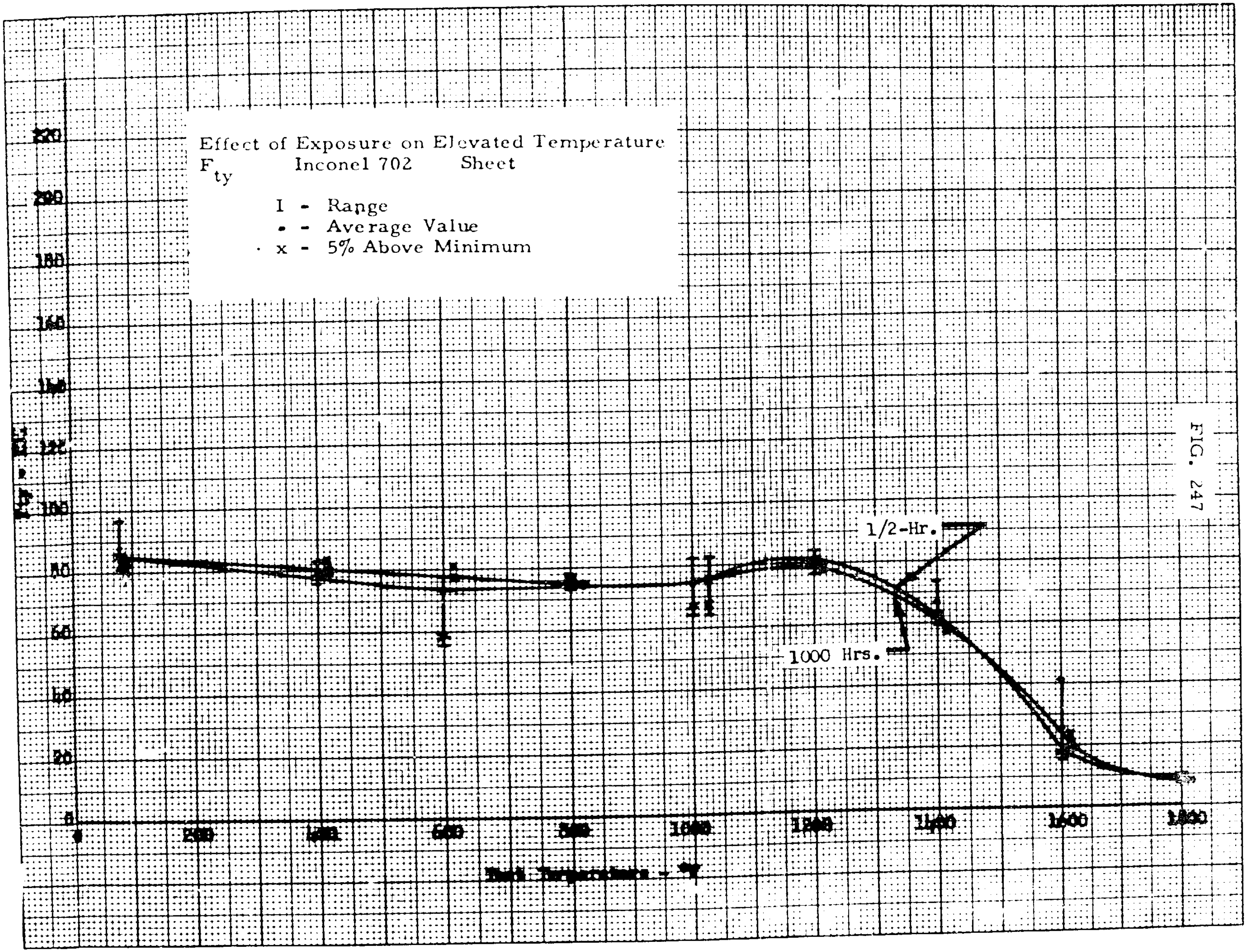

Effect of Exposure on Elevated Temperature
F_{ty} Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1/2-Hr.
1000 Hrs.
0
20
40
60
80
100
120
140
160
180
200
220
200
400
600
800
1000
1200
1400
1600
1800

FIG. 247

FIG. 248

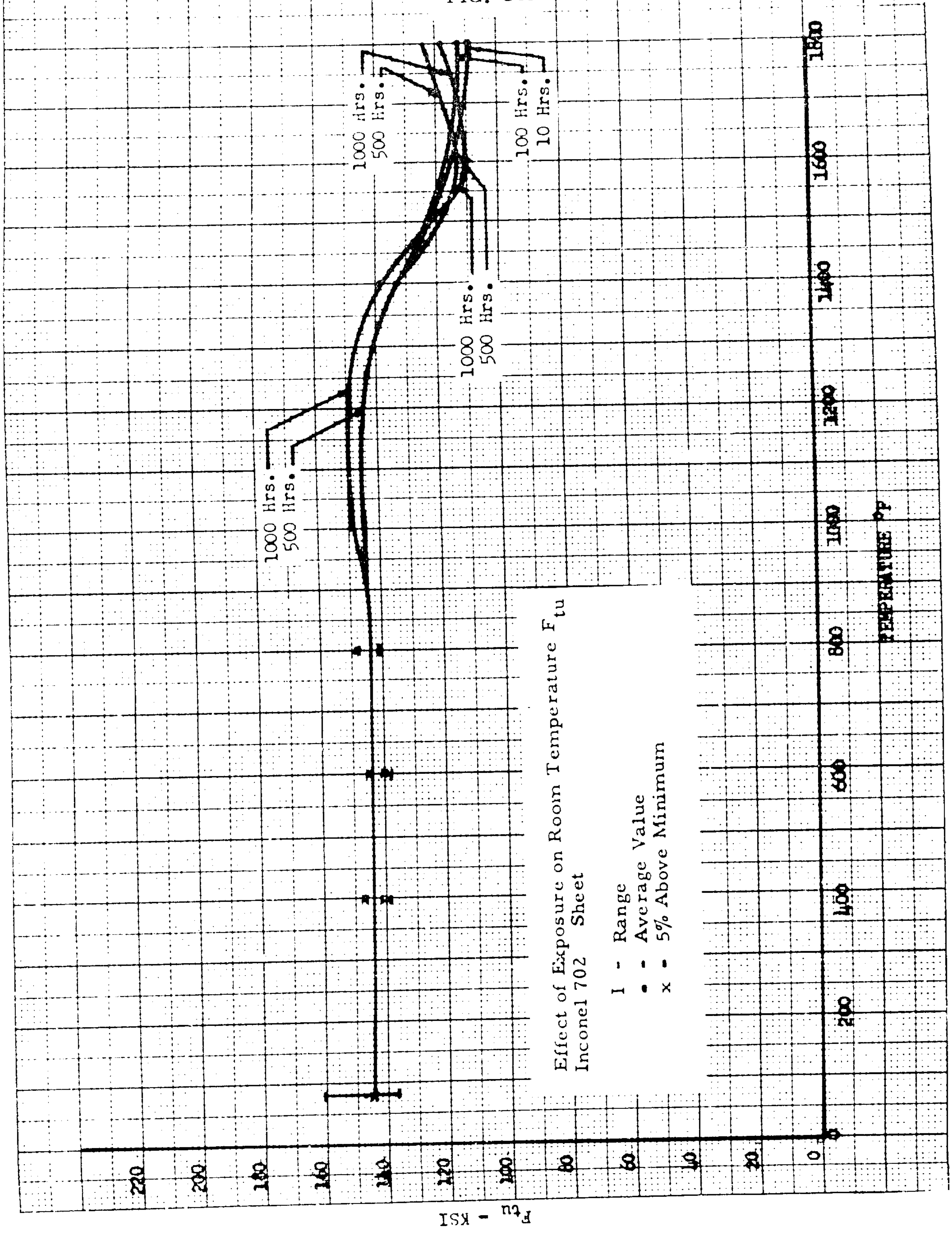
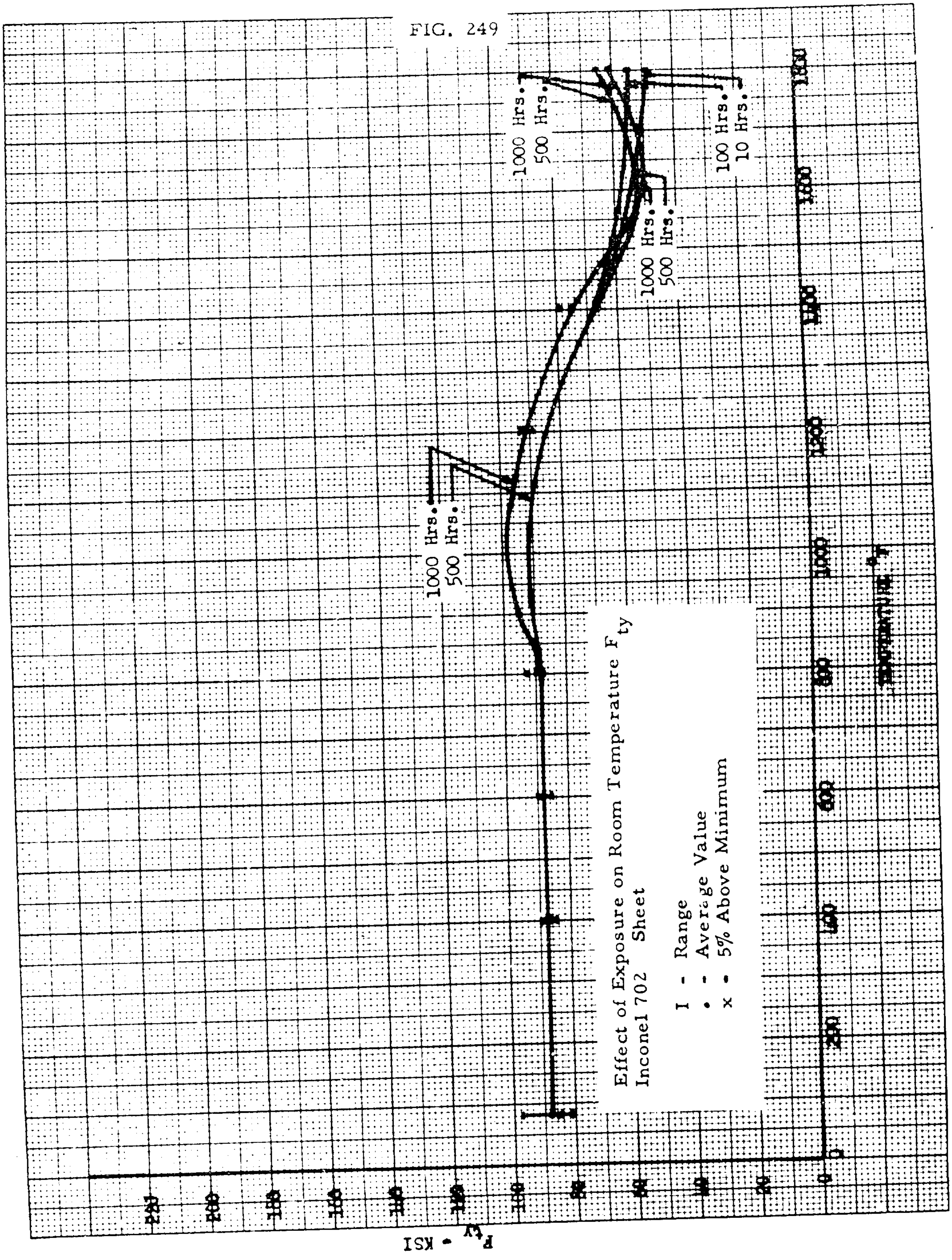
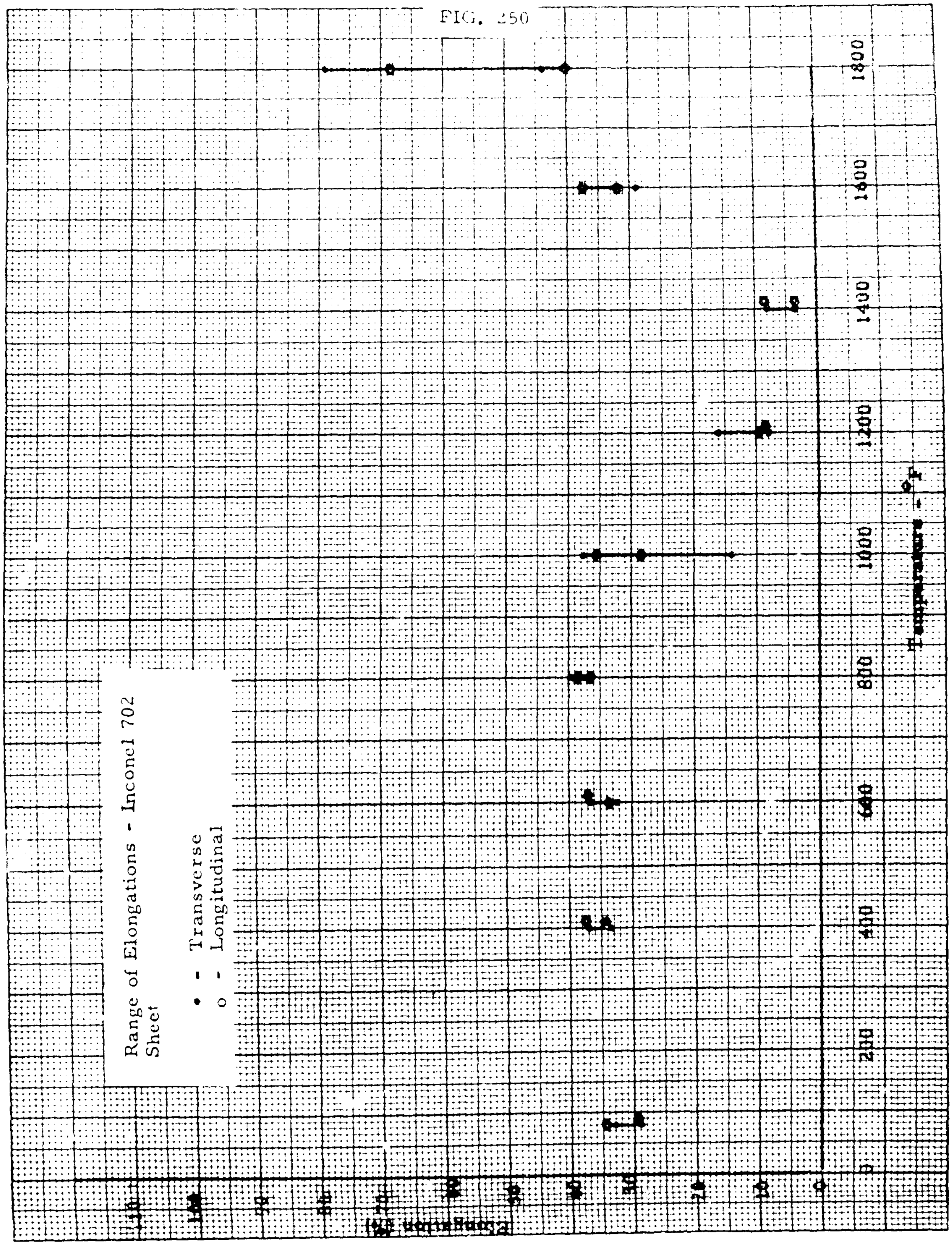

Effect of Exposure on Room Temperature F_{tu}
Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
0
20
40
60
80
100
120
140
160
180
200
220
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE °F
F_{tu} - KSI

FIG. 249



Effect of Exposure on Room Temperature F_{ty}
Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1000 Hrs.
500 Hrs.
1000 Hrs.
500 Hrs.
1000 Hrs.
500 Hrs.
100 Hrs.
10 Hrs.
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE °F
F_{ty} - KSI
20
40
60
80
100
120
140
160
180
200
220

FIG. 260



Range of Elongations - Inconel 702
Sheet
• - Transverse
o - Longitudinal
Elongation (%)
Temperature - °F
0
200
400
600
800
1000
1200
1400
1600
1800
0
10
20
30
40
50
60
70
80
90
100
110

SECTION VII

Section 7.3.2 Compression

FIG. 251

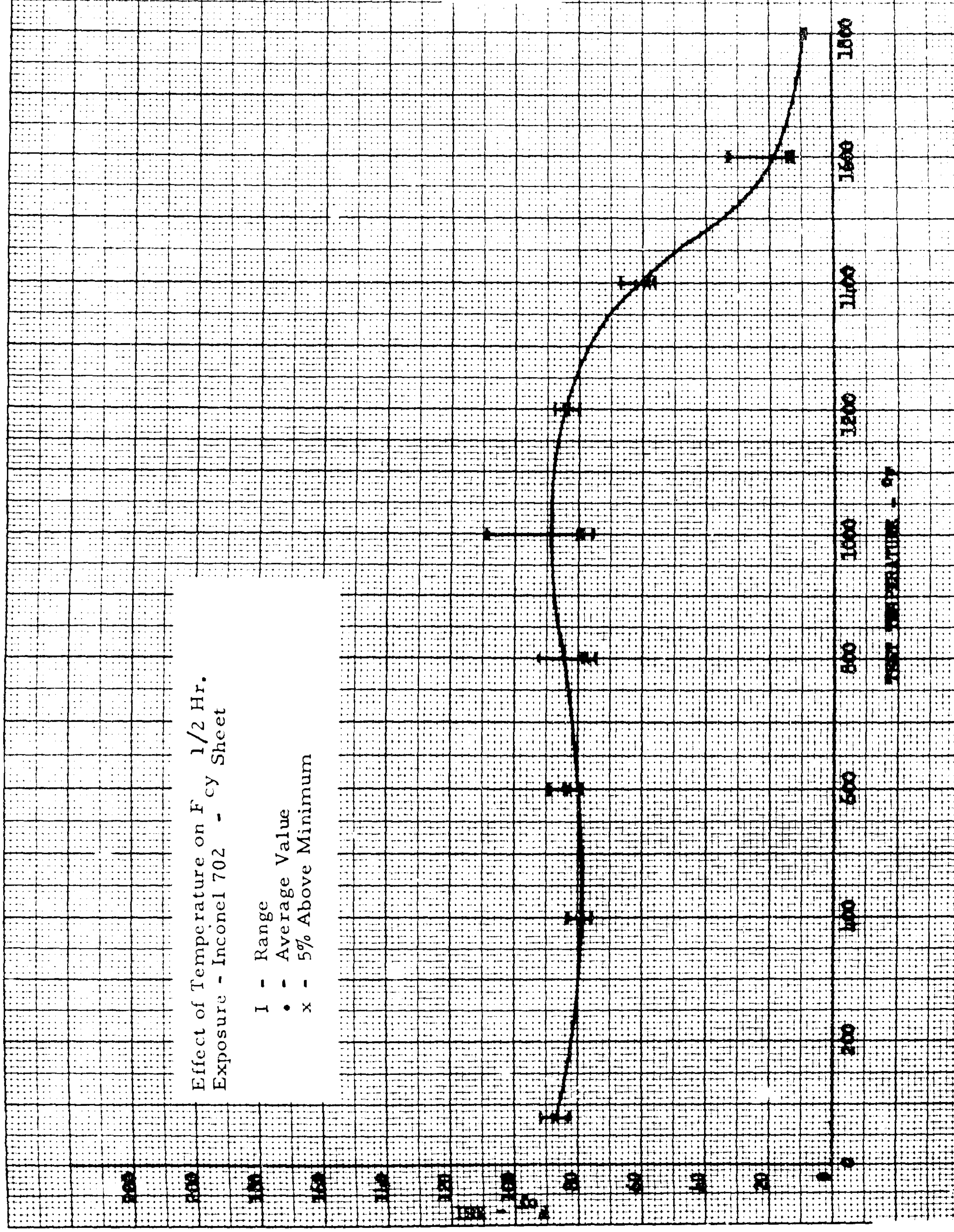

Effect of Temperature on F_{cy} 1/2 Hr.
Exposure - Inconel 702 - Sheet
I - Range
• - Average Value
x - 5% Above Minimum
0
200
400
600
800
1000
1200
1400
1600
1800
20
40
60
80
100
120
140
160
180
200
220

FIG. 252

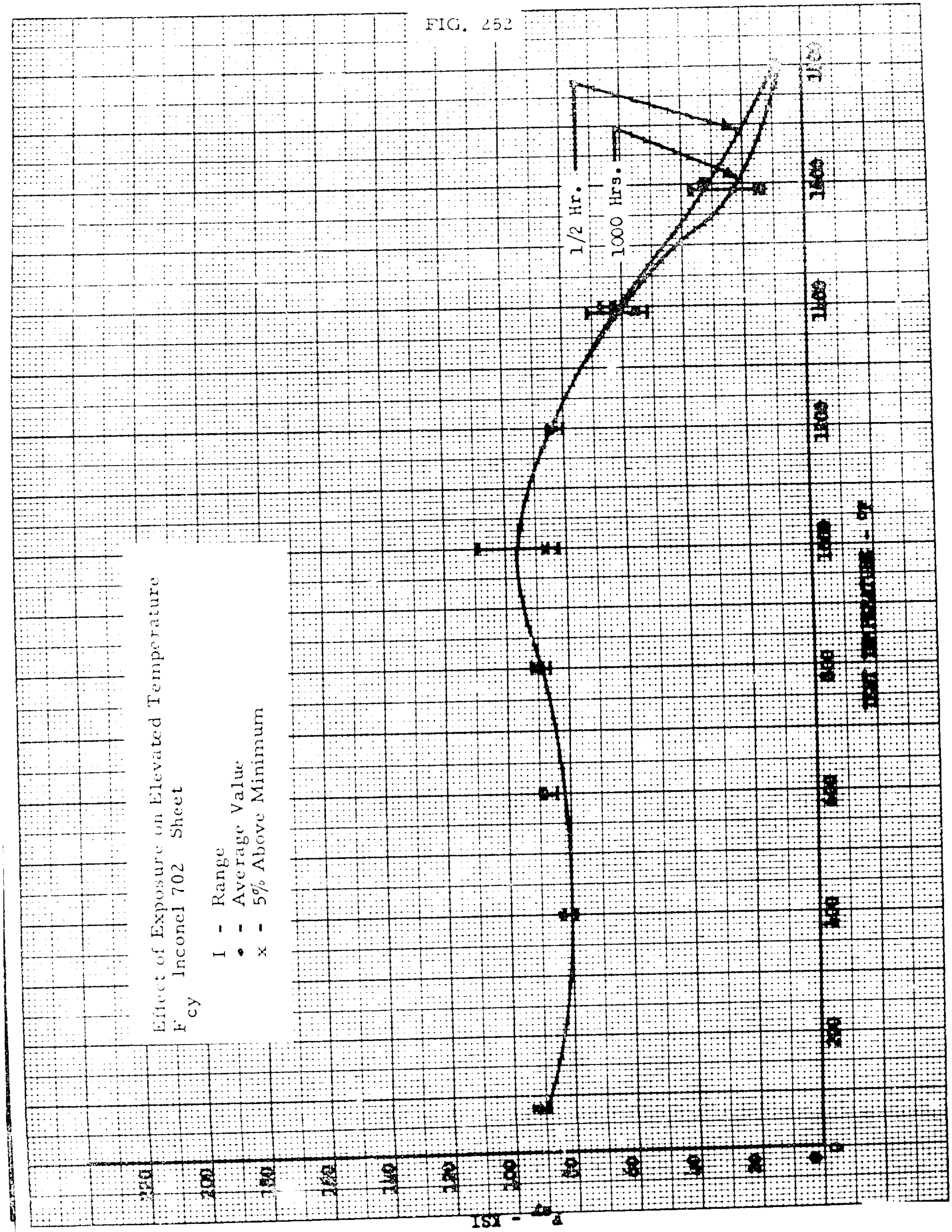
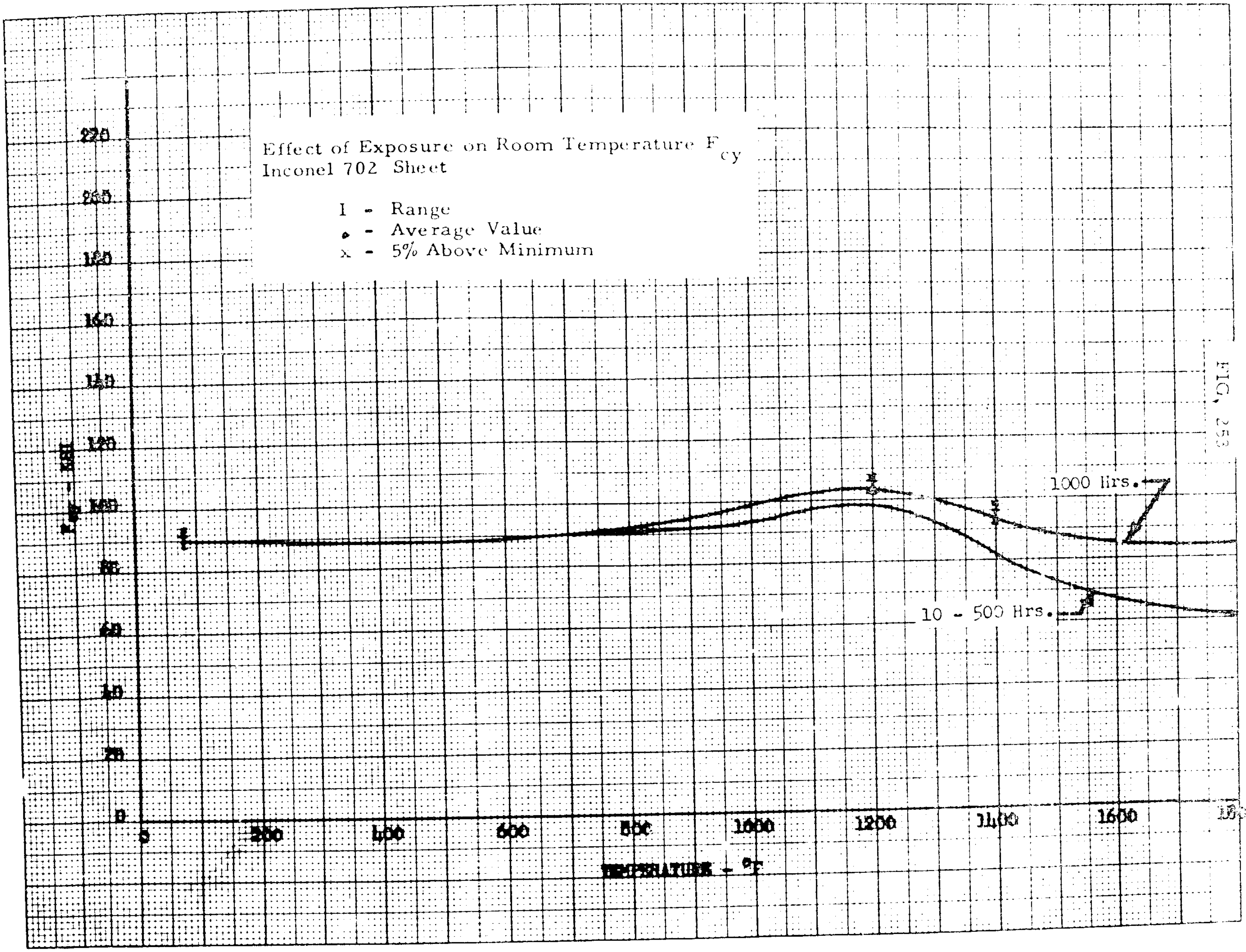

Effect of Exposure on Elevated Temperature
F_{cy} Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1/2 Hr.
1000 Hrs.
TEST TEMPERATURE - °F
F_{cy} - KSI

FIG. 253


Effect of Exposure on Room Temperature F_{cy}
Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1000 Hrs.
10 - 500 Hrs.
220
100
0
0
200
400
600
1000
1200
1600
TEMPERATURE - °F

SECTION VII

SECTION 7.3.3 BEARING

FIG. 254

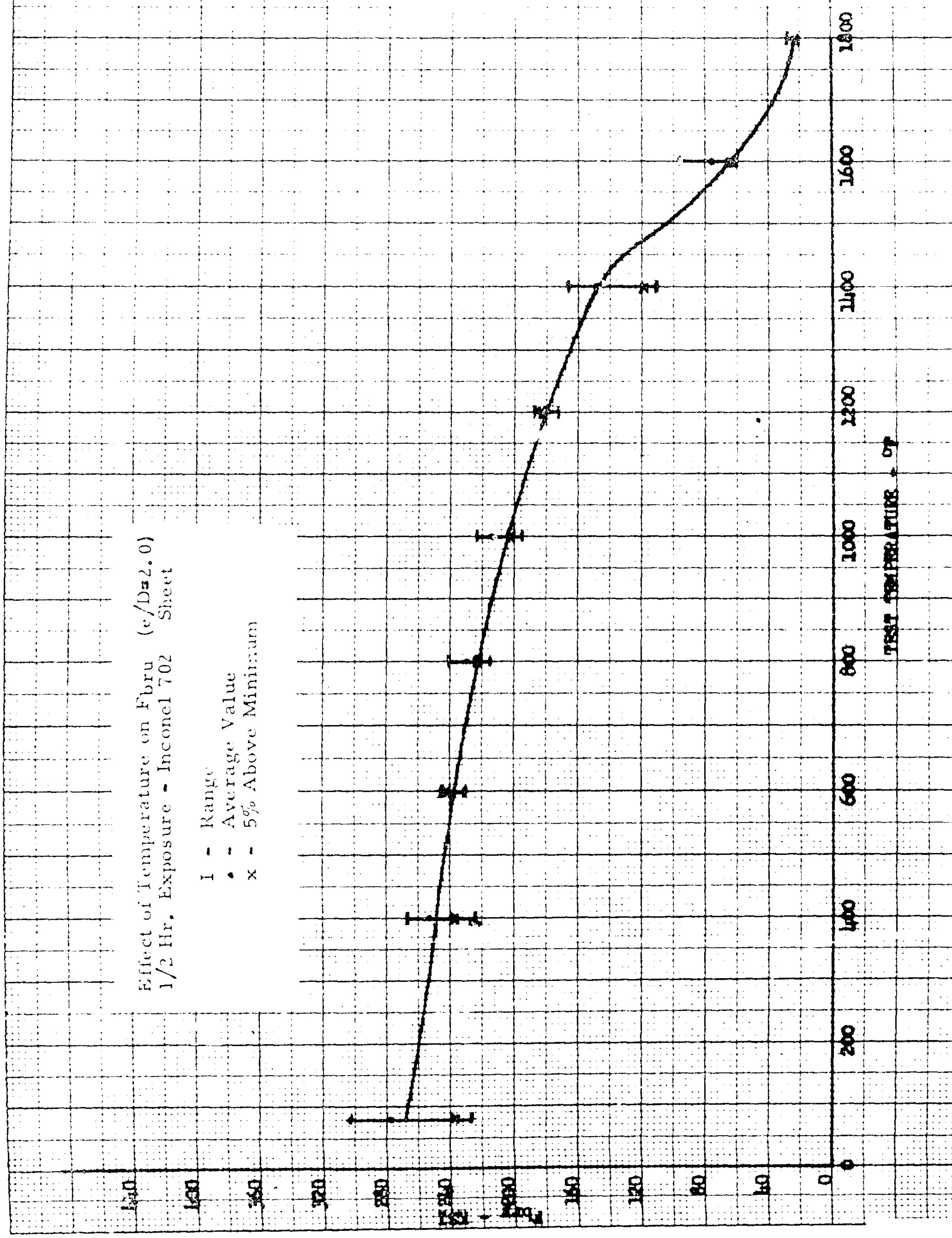

Effect of Temperature on Fbru (e/D=2.0)
1/2 Hr. Exposure - Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
TEST TEMPERATURE - °F
0
200
400
600
800
1000
1200
1400
1600
1800
0
40
80
120
160
320
360

FIG. 255

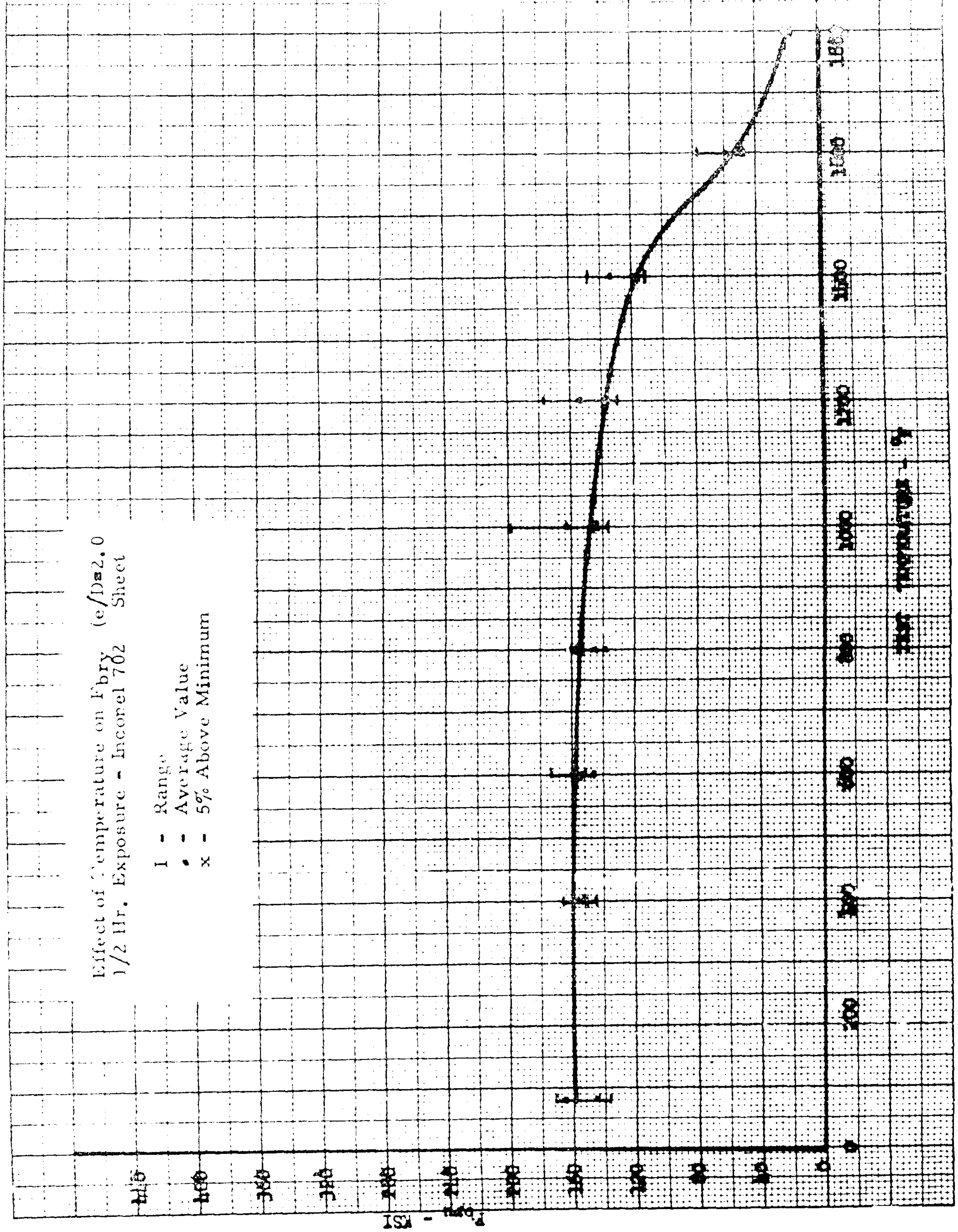
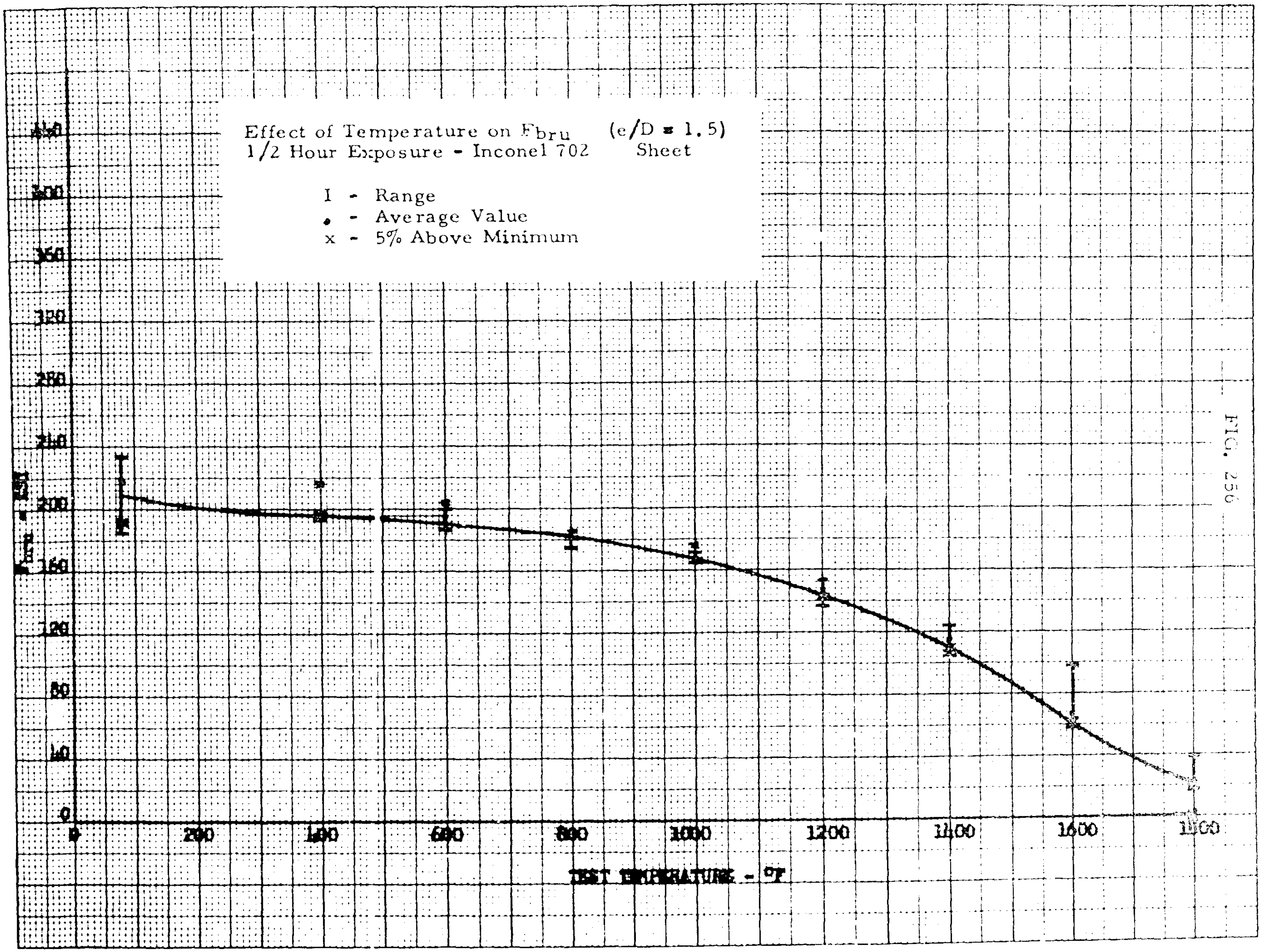
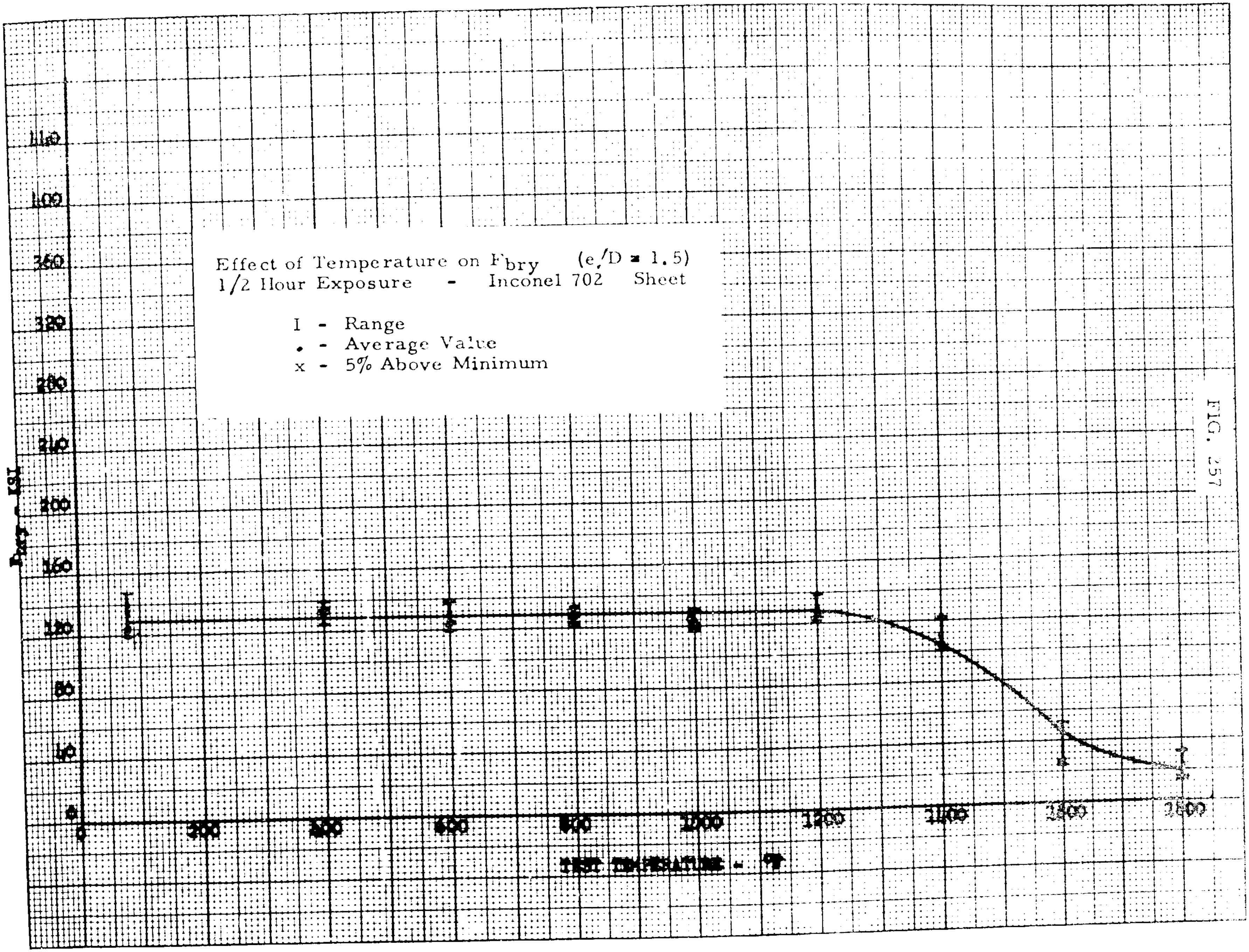

Effect of Temperature on Fbry (e/D≥2.0
1/2 Hr. Exposure - Incorel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
TEST TEMPERATURE - °F
Fbry - KSI
0
40
80
120
160
200
240
280
320
360
400
440
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 256

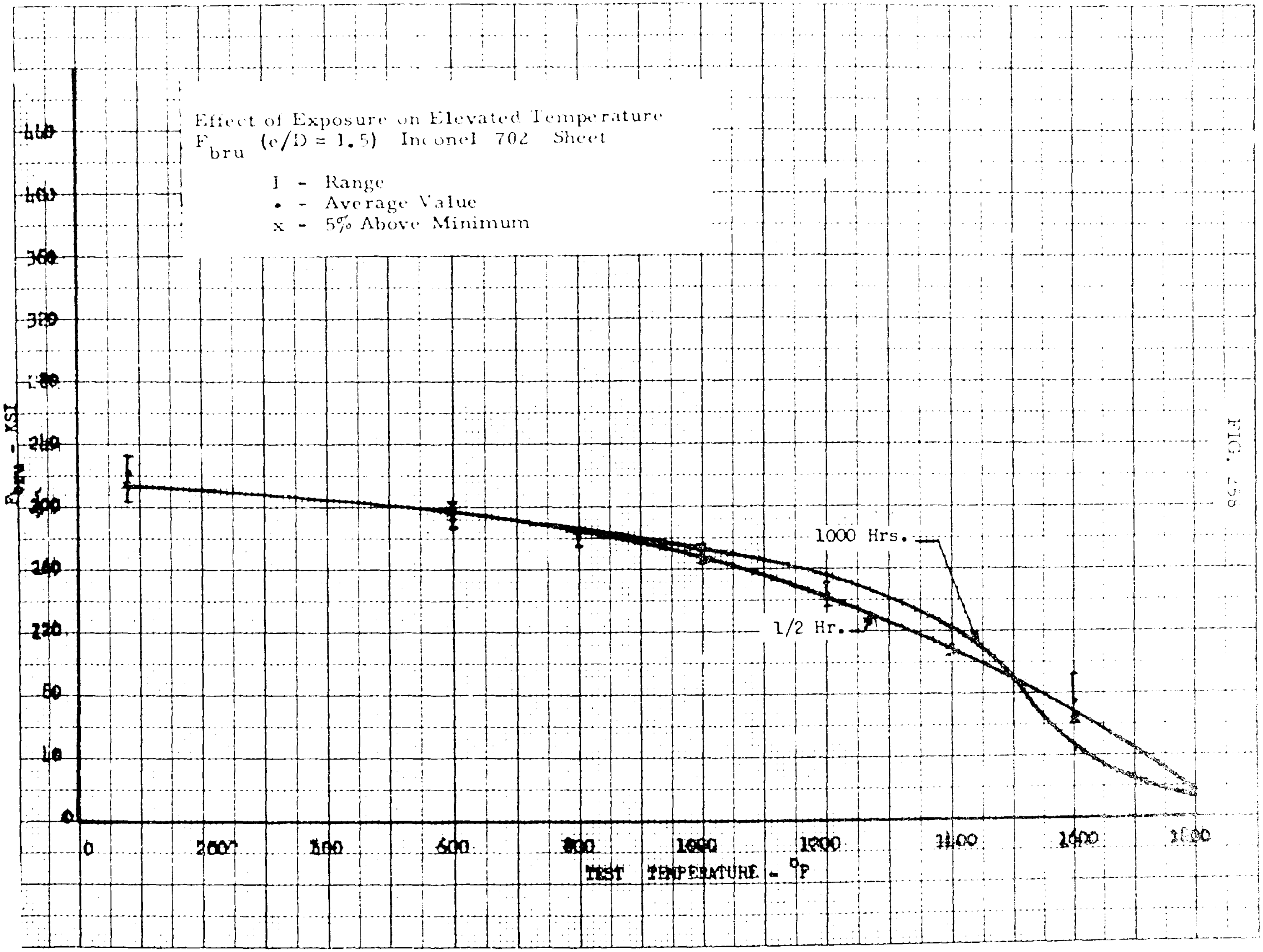


Effect of Temperature on Fbru (e/D = 1.5)
1/2 Hour Exposure - Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
0
40
80
120
160
200
240
280
320
360
400
440
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE - °F

FIG. 257



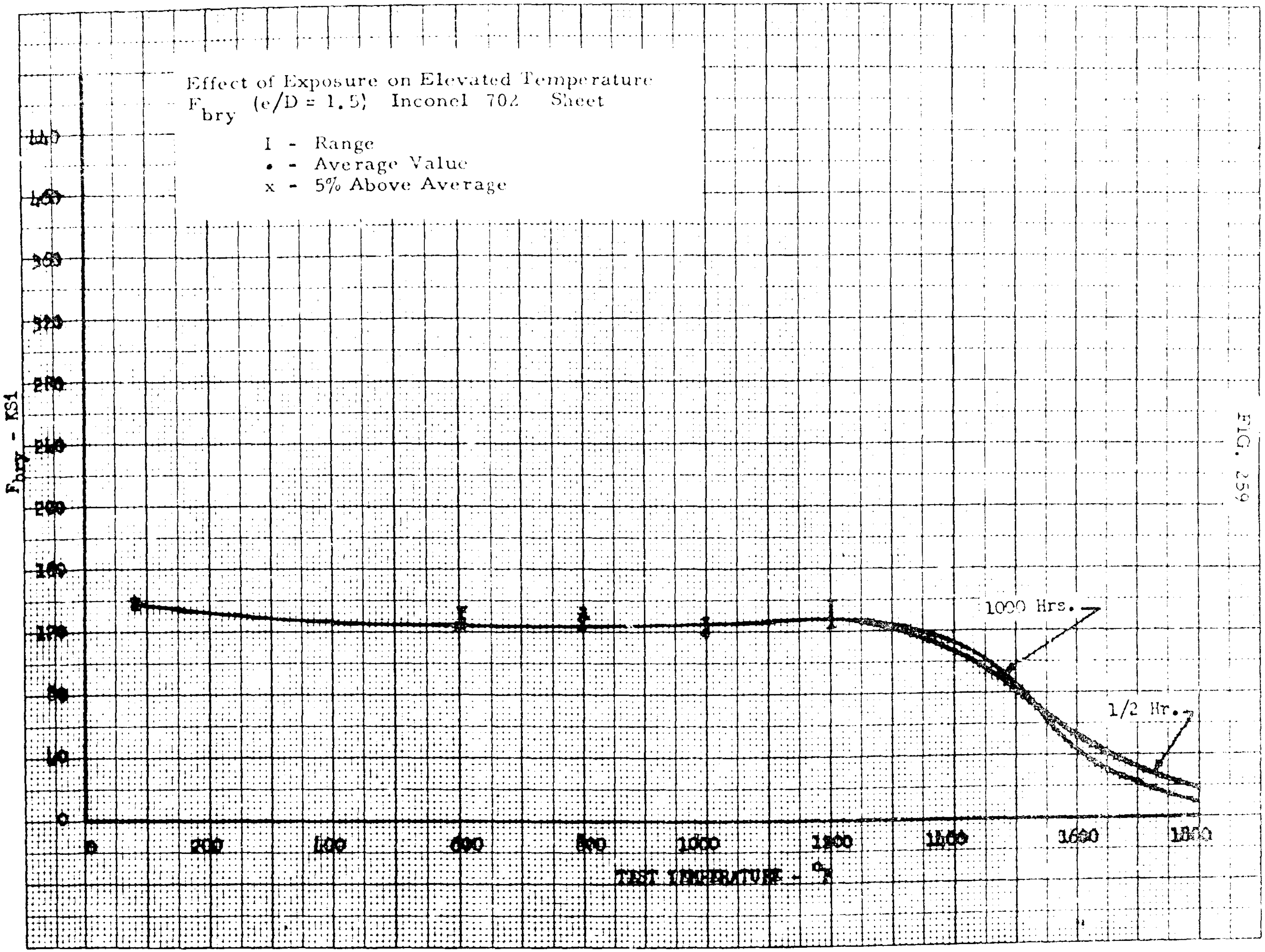
Effect of Temperature on F_{bry} $(e/D = 1.5)$
1/2 Hour Exposure - Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
F_{bry} - KSI
440
400
360
320
280
240
200
160
120
80
40
0
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE - °F



Effect of Exposure on Elevated Temperature
F_{bru} (e/D = 1.5) Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1000 Hrs.
1/2 Hr.
TEST TEMPERATURE - °F
F_{bru} - KSI

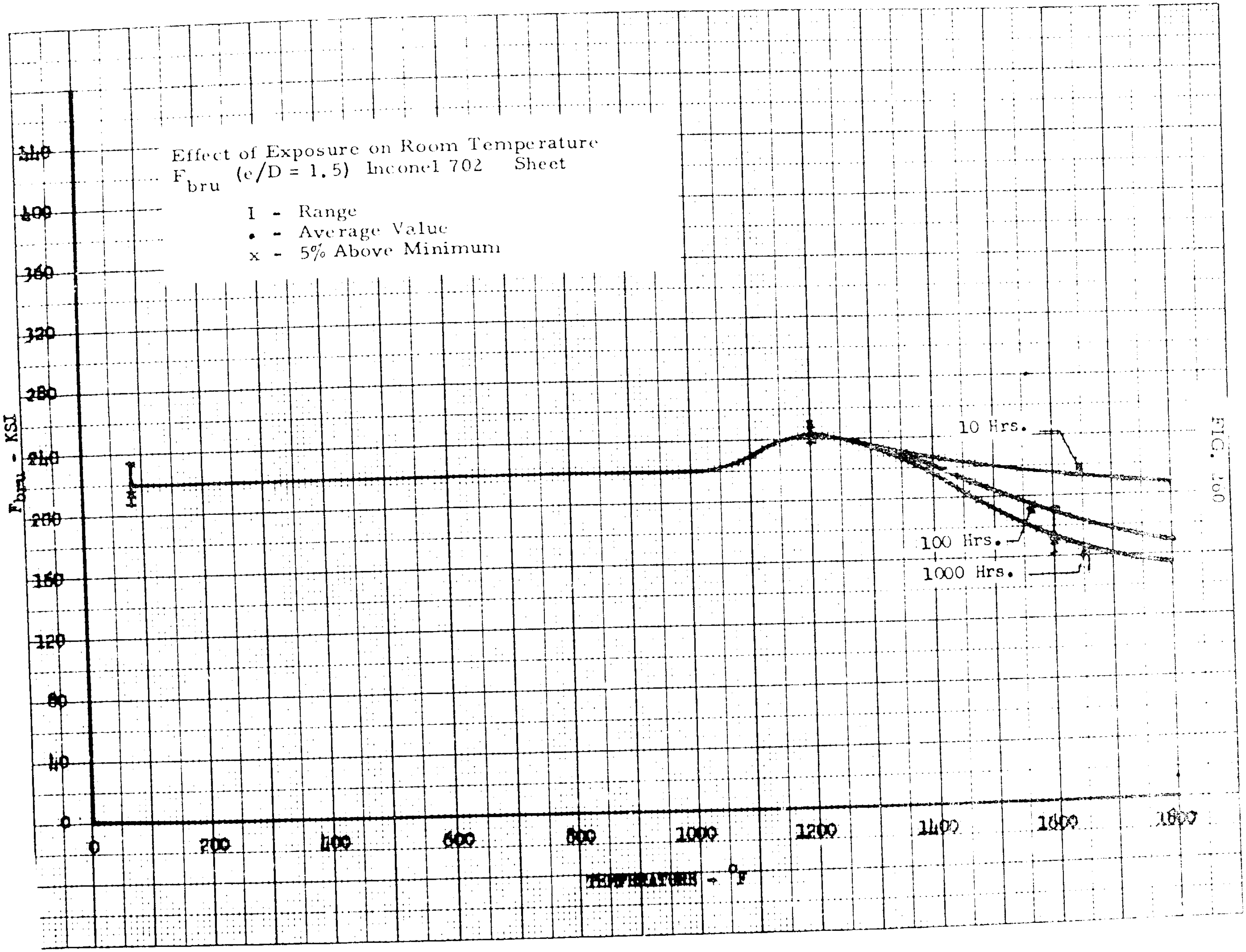
FIG. 258

FIG. 259



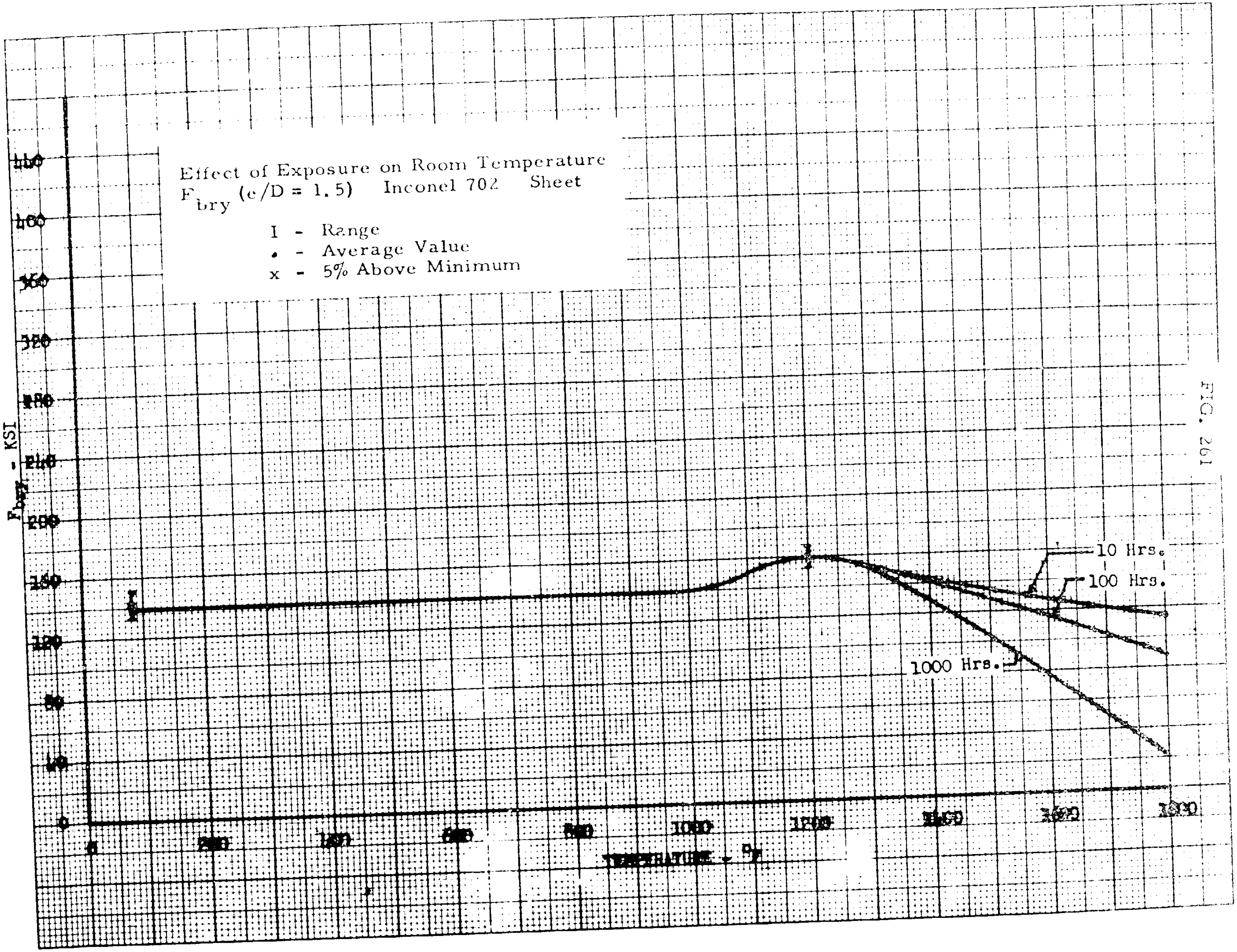
Effect of Exposure on Elevated Temperature
F_{bry} (e/D = 1.5) Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Average
1000 Hrs.
1/2 Hr.
F_{bry} - KSI
TEST TEMPERATURE - °F

FIG. 260



Effect of Exposure on Room Temperature
F_{bru} (e/D = 1.5) Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
10 Hrs.
100 Hrs.
1000 Hrs.
F_{bru} - KSI
440
400
360
320
280
240
200
160
120
80
40
0
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE - °F

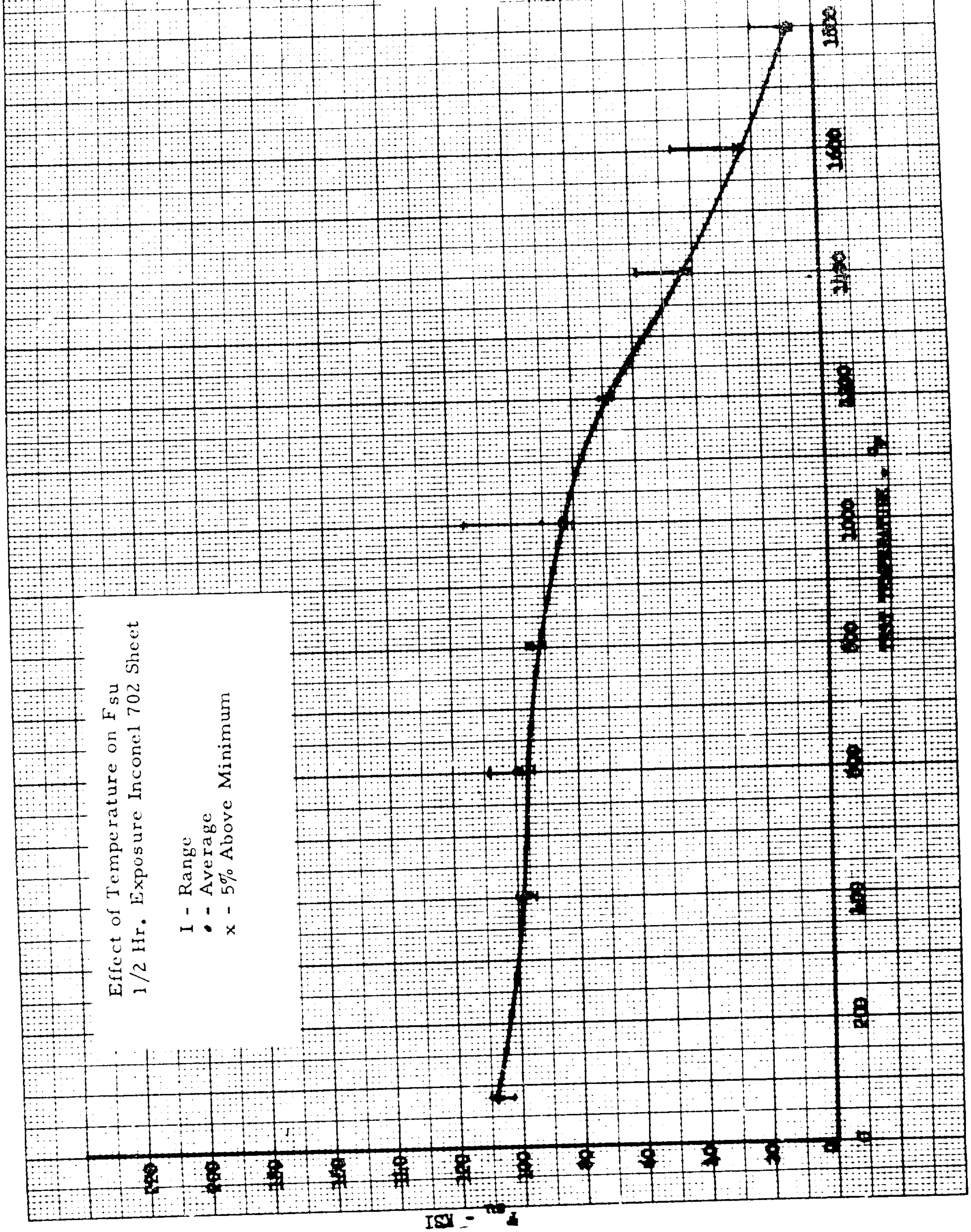
FIG. 261


Effect of Exposure on Room Temperature
F_{bry} (e/D = 1.5) Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
10 Hrs.
100 Hrs.
1000 Hrs.
F_{bry} - KSI
0
40
80
120
160
200
240
280
320
360
400
440
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE - °F

SECTION VII

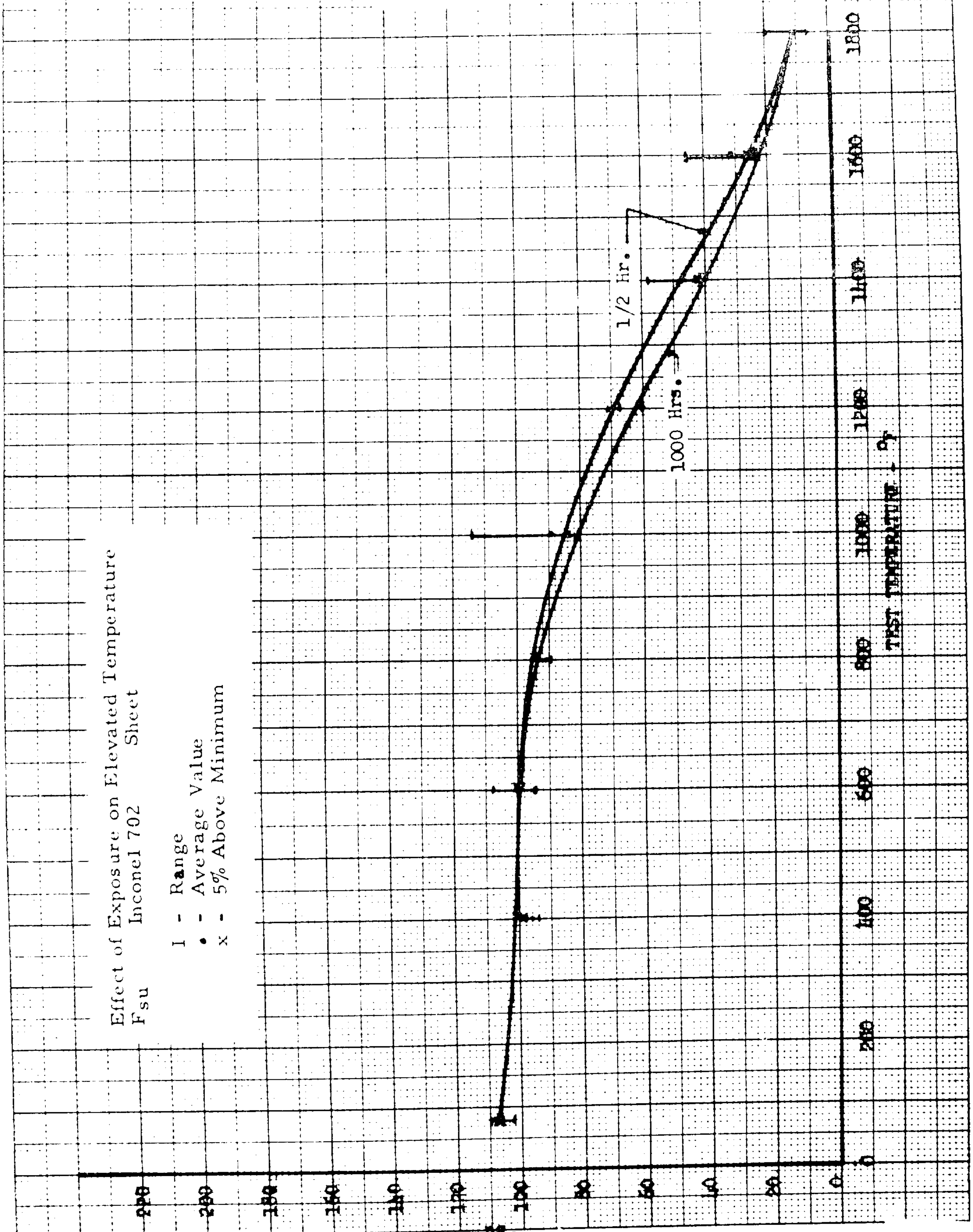
SECTION 7.3.4 SHEAR

FIG. 262



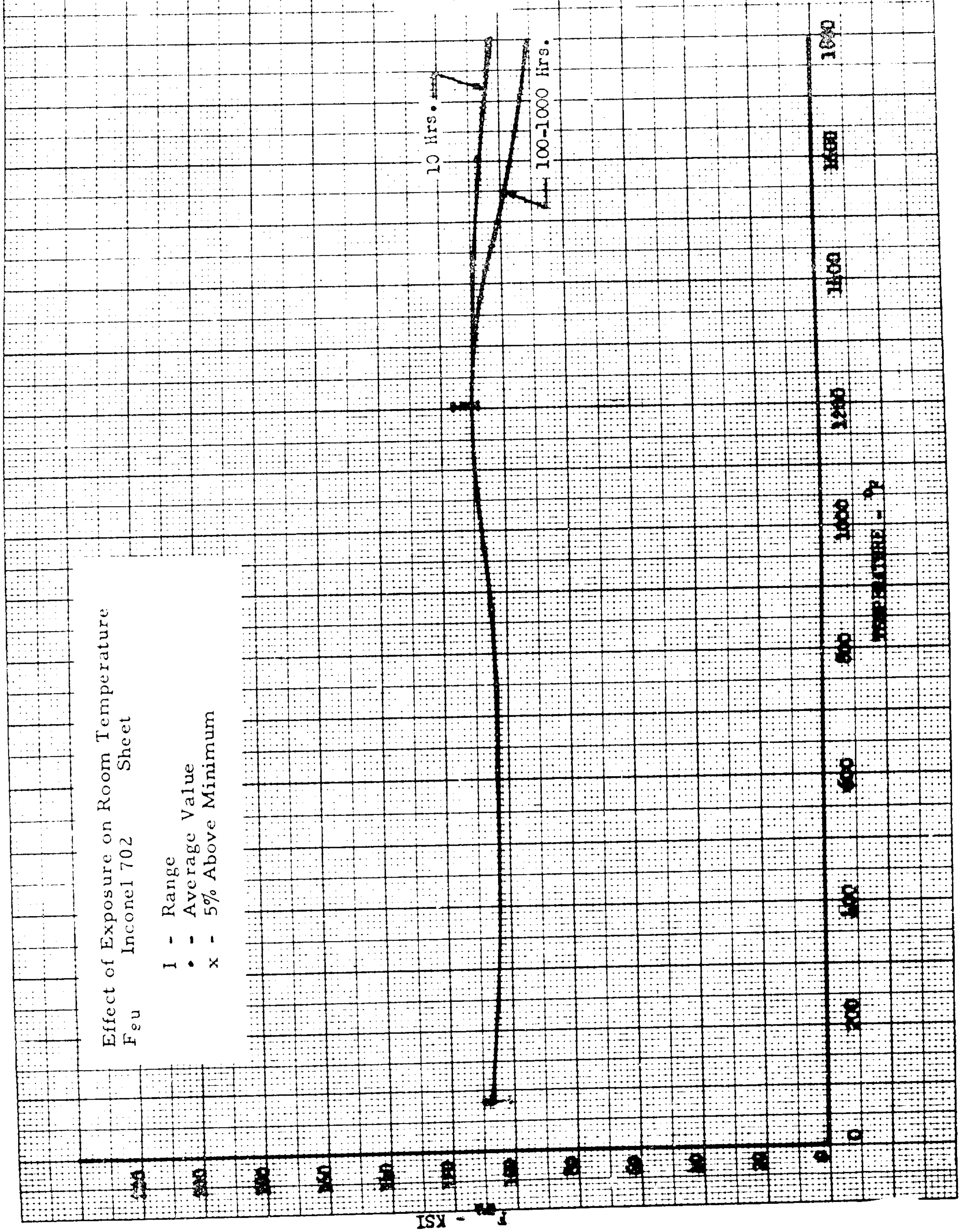
Effect of Temperature on Fsu
1/2 Hr. Exposure Inconel 702 Sheet
I - Range
• - Average
x - 5% Above Minimum

FIG. 263



Effect of Exposure on Elevated Temperature
Fsu Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
1/2 Hr.
1000 Hrs.
TEST TEMPERATURE - °F
Fsu - KSI
0
200
400
600
800
1000
1200
1400
1600
1800
20
40
60
80
100
120
140
160
180

FIG. 264



Effect of Exposure on Room Temperature
Fsu Inconel 702 Sheet
I - Range
• - Average Value
x - 5% Above Minimum
10 Hrs.
100-1000 Hrs.
0
200
400
600
800
1000
1200
1400
1600
TEMPERATURE - °F
0
20
40
60
80
100
120
140
160
180
200
220
240
F - KSI

SECTION VII

SECTION 7.3.5 CREEP

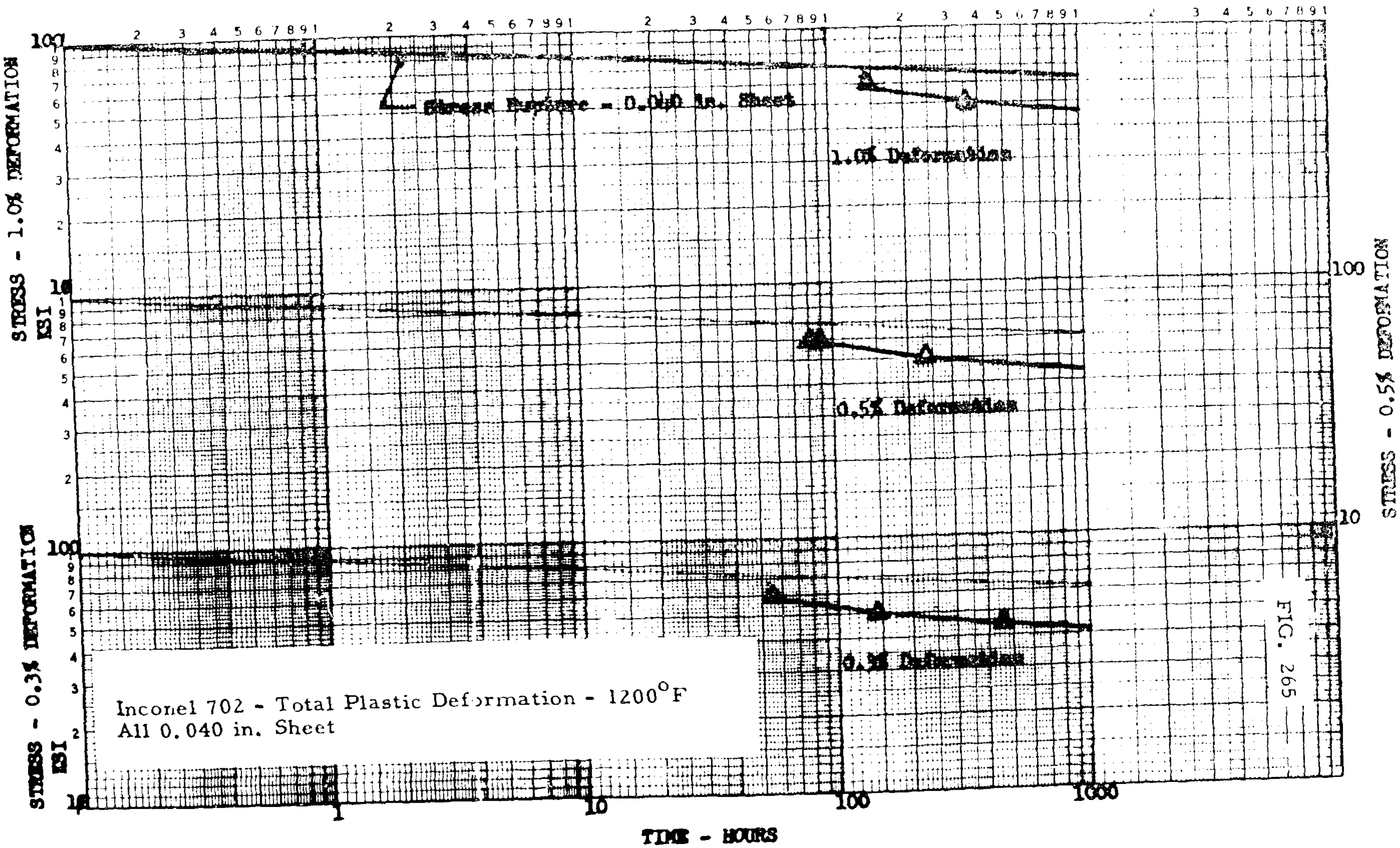
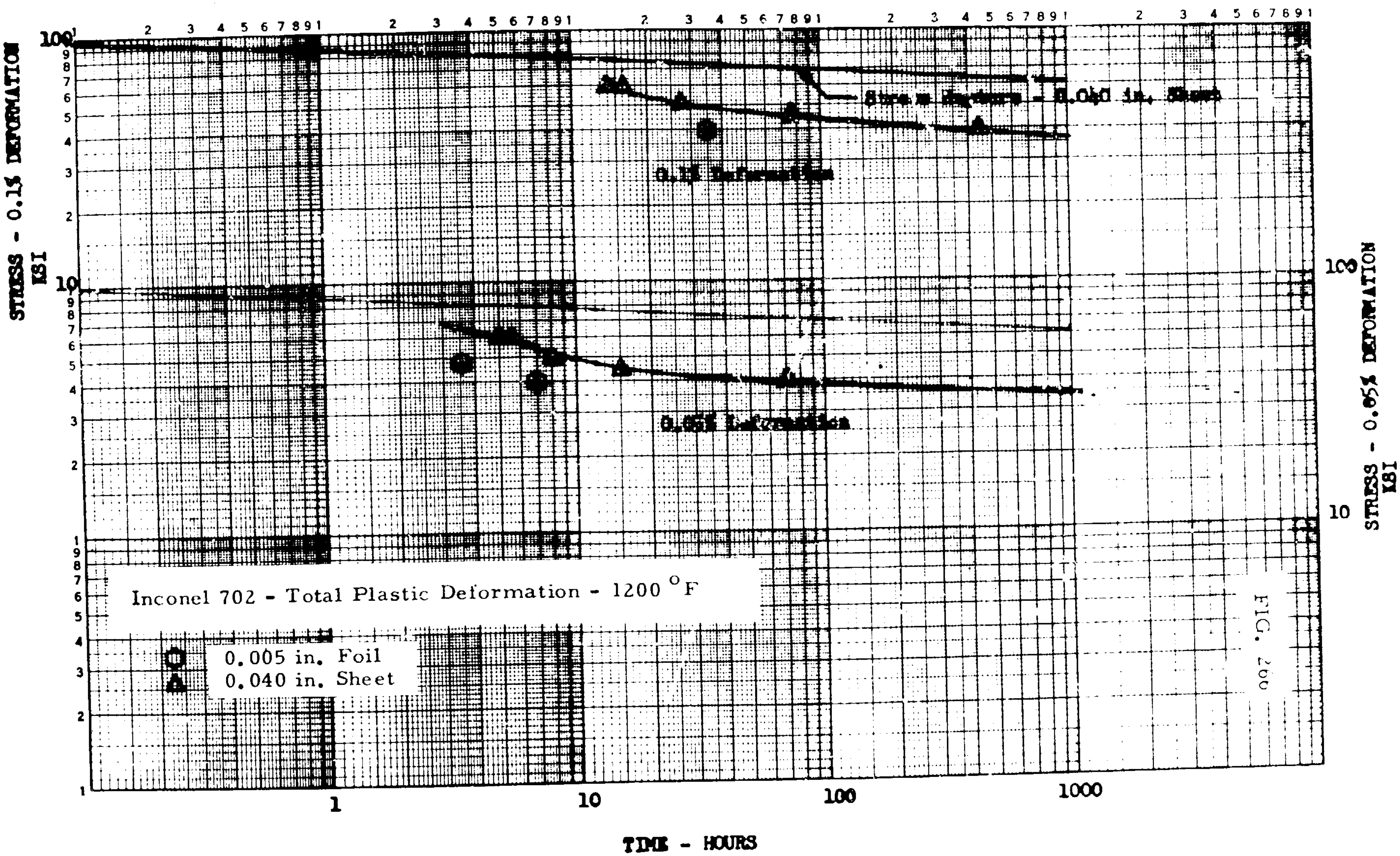


FIG. 265

Inconel 702 - Total Plastic Deformation - 1200°F
All 0.040 in. Sheet



STRESS - 0.1% DEFORMATION KSI
STRESS - 0.05% DEFORMATION KSI
TIME - HOURS
Inconel 702 - Total Plastic Deformation - 1200 °F
0.005 in. Foil
0.040 in. Sheet
0.1% Deformation
0.05% Deformation
Stress Rupture - 0.040 in. Sheet

FIG. 260

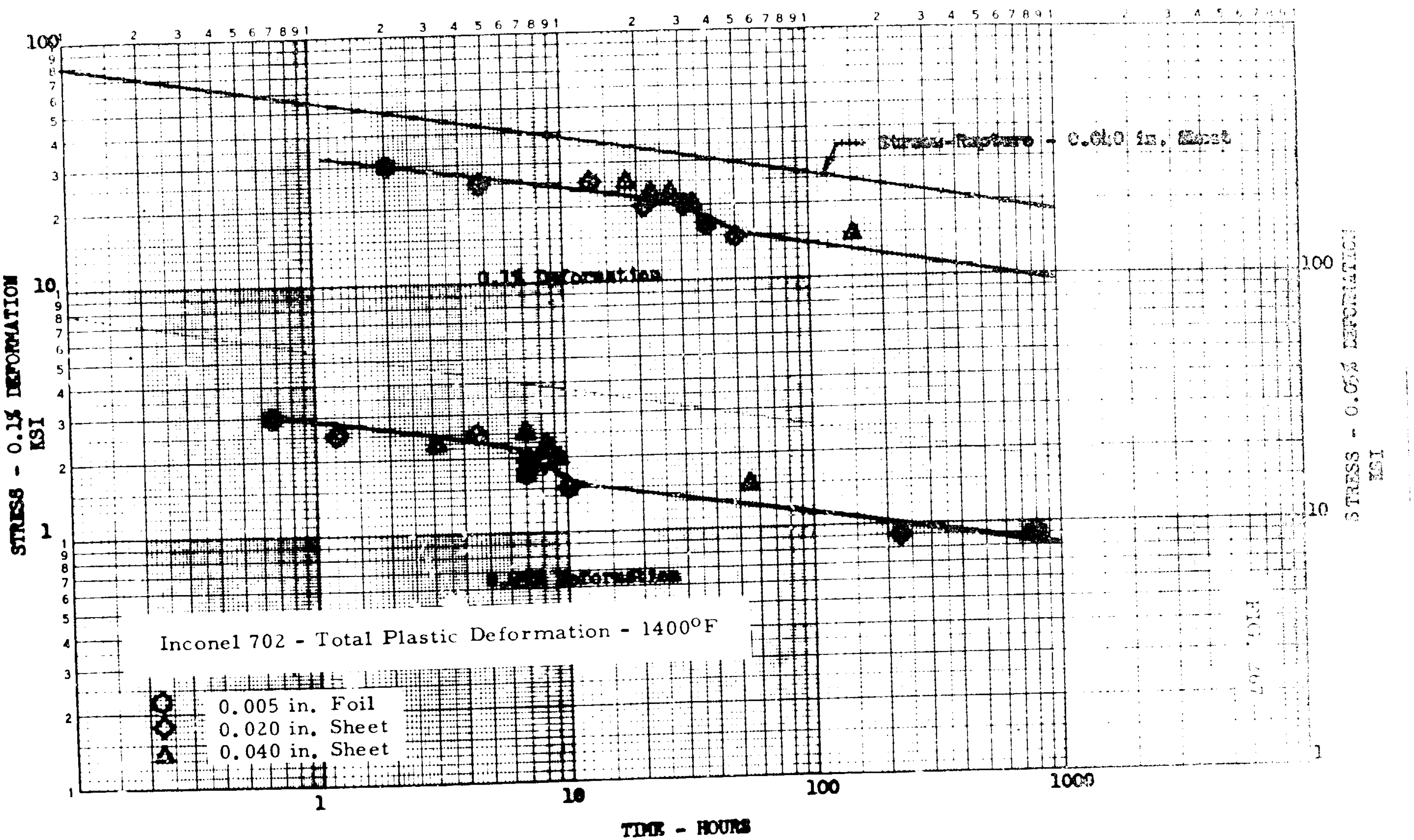

Stress-Rupture - 0.040 in. Sheet
0.1% Deformation
Inconel 702 - Total Plastic Deformation - 1400°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
STRESS - 0.1% DEFORMATION KSI
STRESS - 0.05% DEFORMATION KSI
TIME - HOURS

FIG. 267

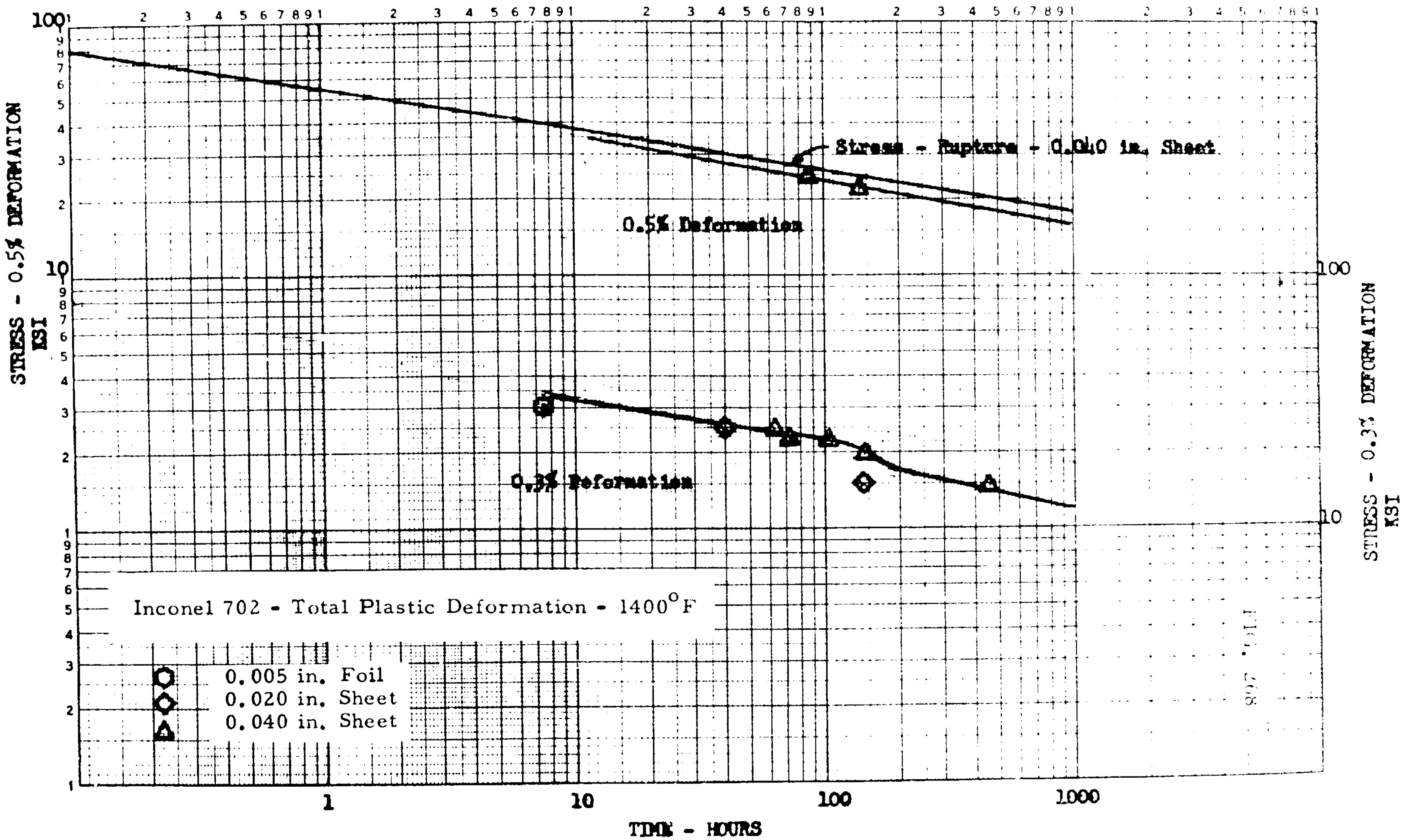
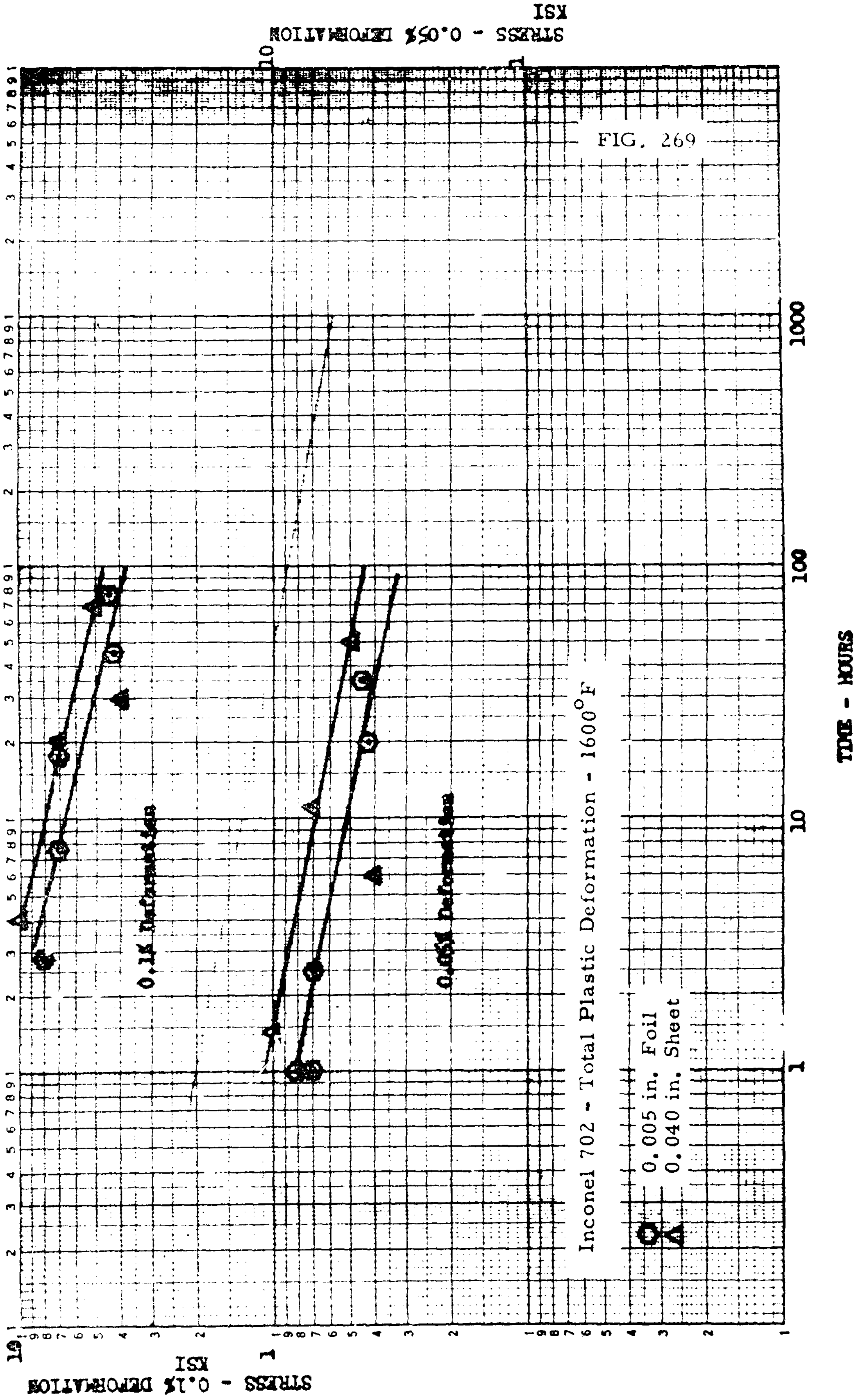
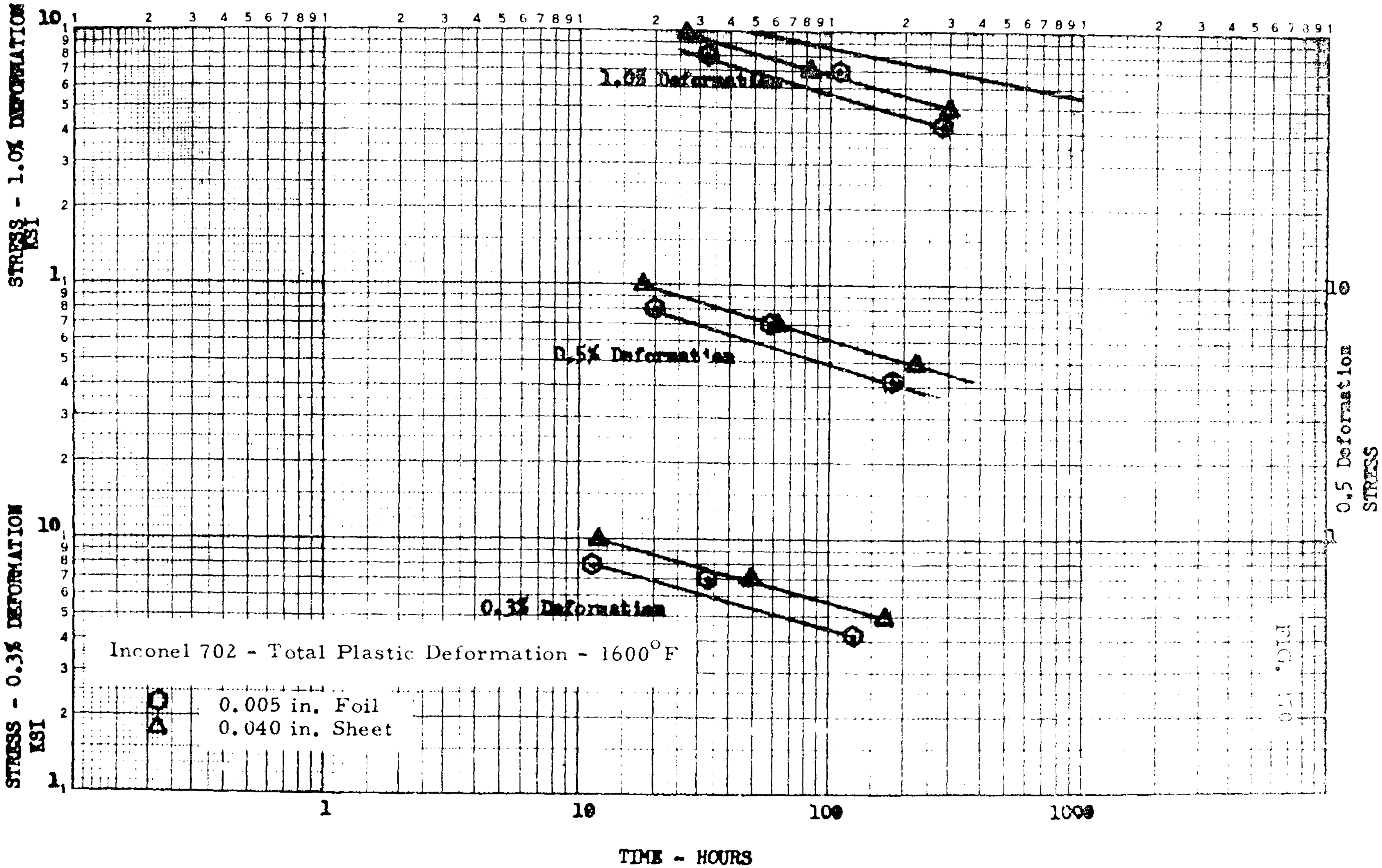

Stress - Rupture - 0.040 in. Sheet
0.5% Deformation
0.3% Deformation
Inconel 702 - Total Plastic Deformation - 1400°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
STRESS - 0.5% DEFORMATION KSI
STRESS - 0.3% DEFORMATION KSI
TIME - HOURS
1
10
100
1000

FIG. 268



STRESS - 0.05% DEFORMATION
KSI
STRESS - 0.1% DEFORMATION
KSI
TIME - HOURS
Inconel 702 - Total Plastic Deformation - 1600°F
0.005 in. Foil
0.040 in. Sheet
0.1% Deformation
0.05% Deformation
10
1
100
1000

FIG. 269


Inconel 702 - Total Plastic Deformation - 1600°F
0.005 in. Foil
0.040 in. Sheet
1.0% Deformation
0.5% Deformation
0.3% Deformation
STRESS - 1.0% DEFORMATION KSI
STRESS - 0.3% DEFORMATION KSI
0.5 Deformation STRESS KSI
TIME - HOURS
1
10
100
1000

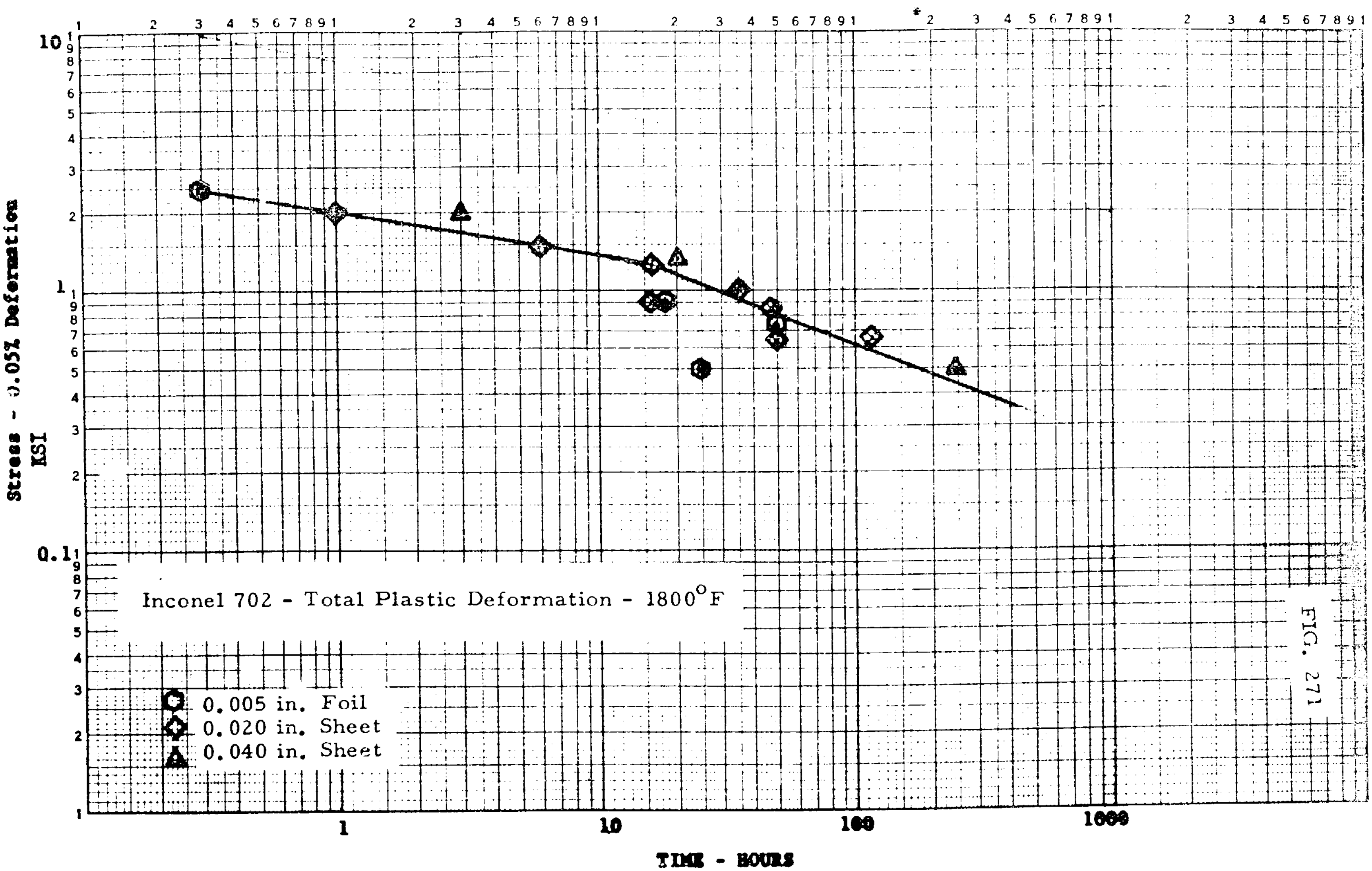


FIG. 271
Inconel 702 - Total Plastic Deformation - 1800°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
Stress - 0.05% Deformation
KSI
TIME - HOURS

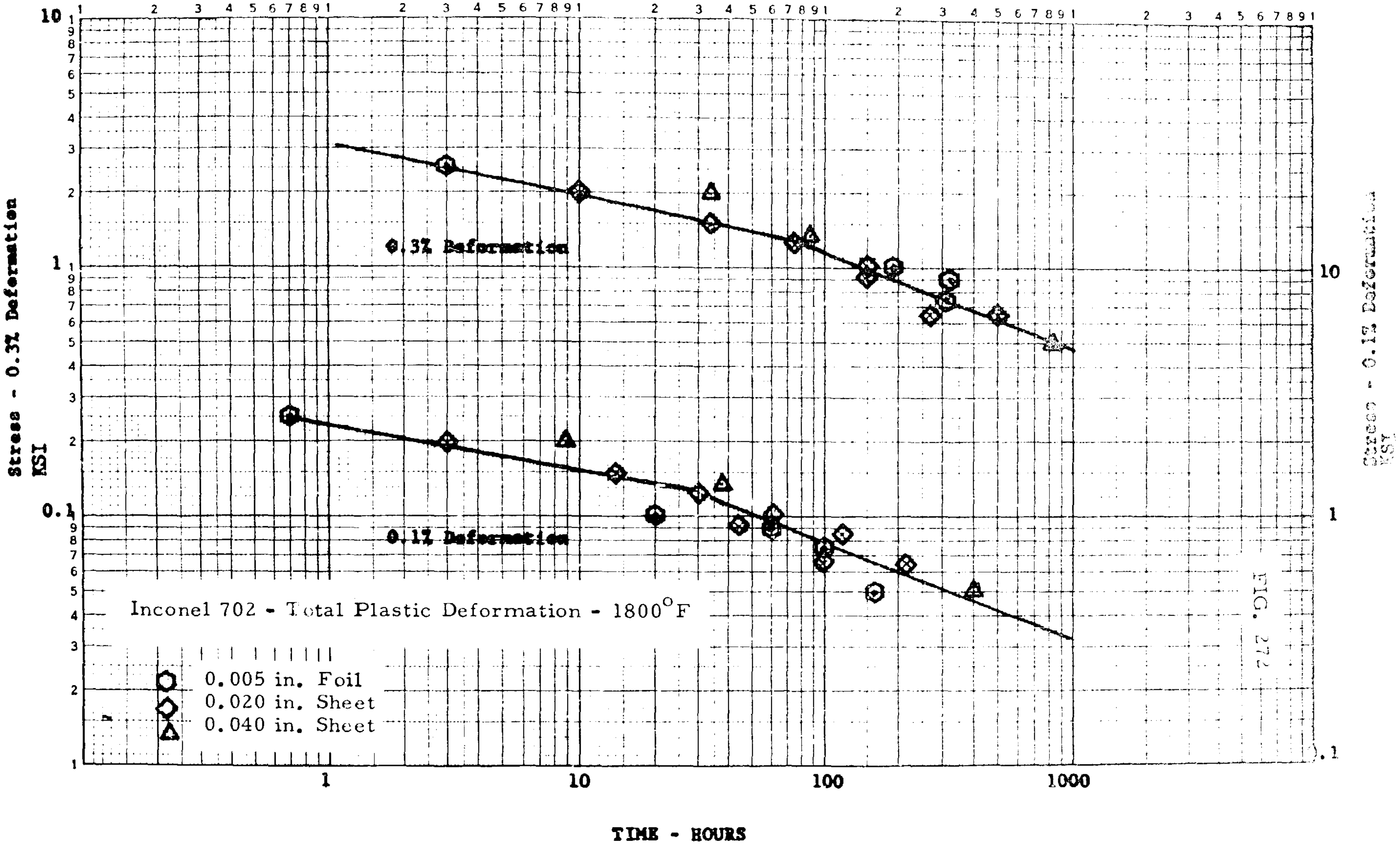
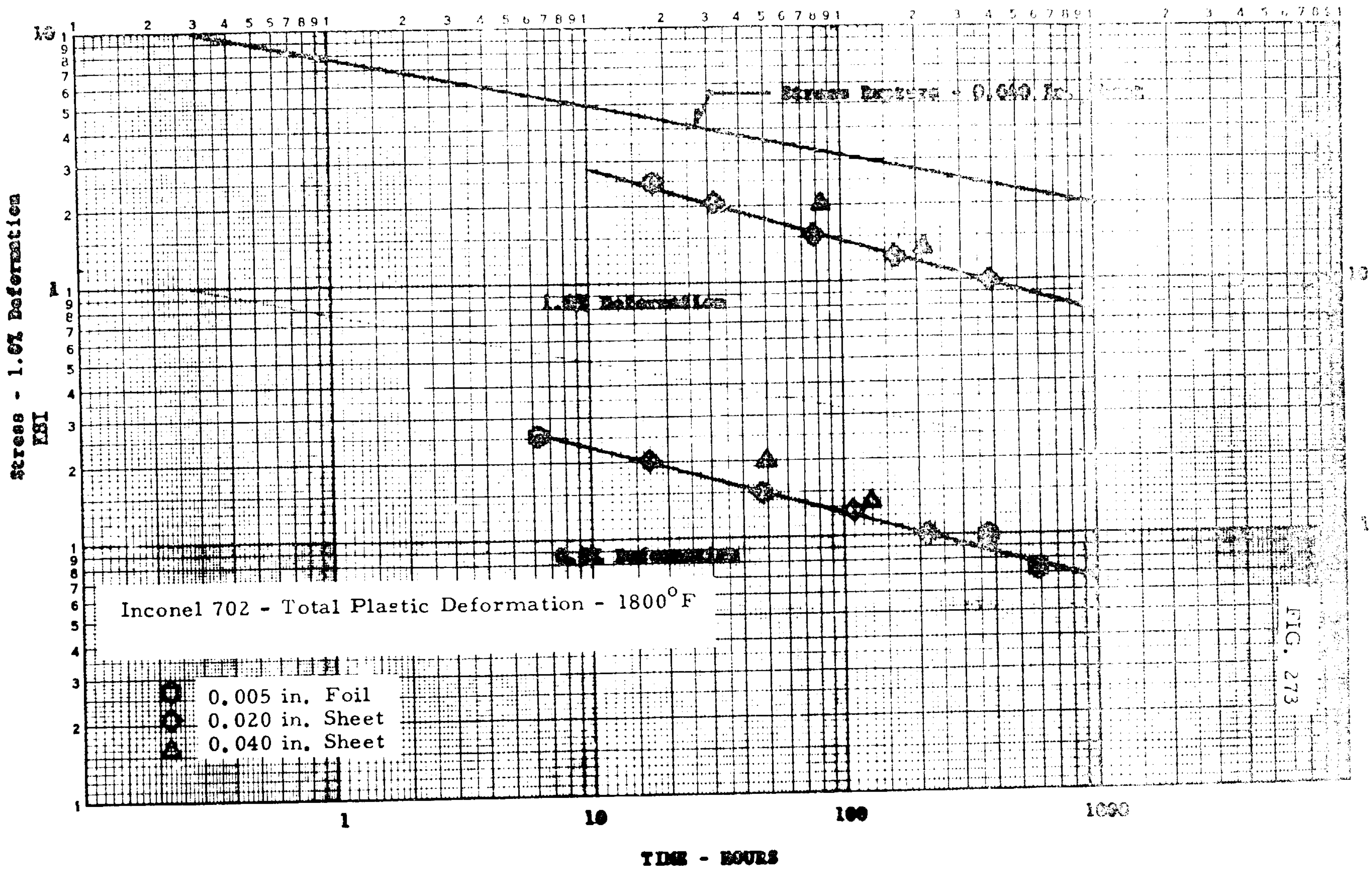

Inconel 702 - Total Plastic Deformation - 1800°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
0.3% Deformation
0.1% Deformation
Stress - 0.3% Deformation
KSI
Stress - 0.1% Deformation
KSI
TIME - HOURS
1
10
100
1000
0.1

FIG. 272



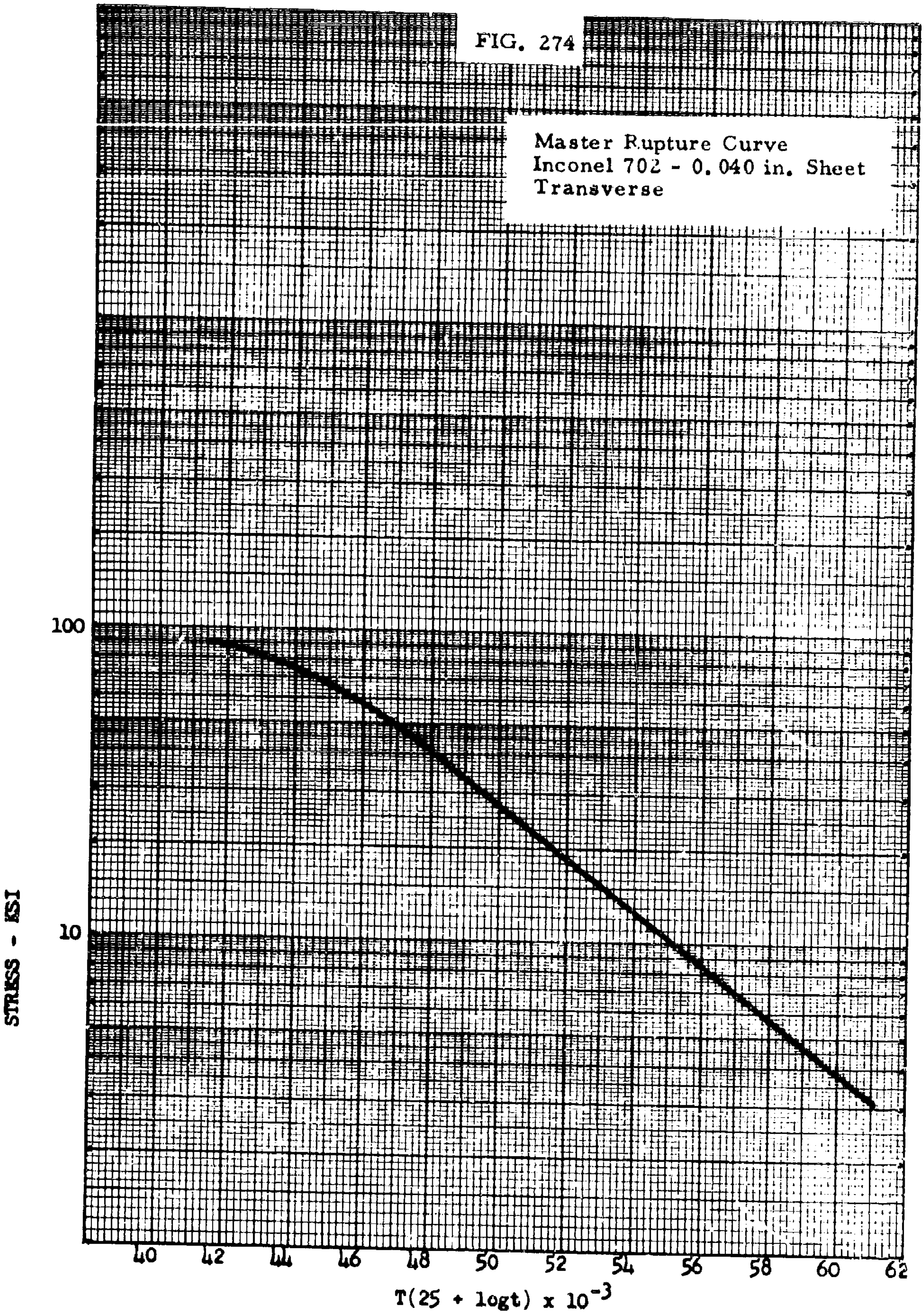
Stress Rupture - 0.040 in.
1.0% Deformation
0.5% Deformation
Inconel 702 - Total Plastic Deformation - 1800°F
0.005 in. Foil
0.020 in. Sheet
0.040 in. Sheet
Stress - 1.0% Deformation
KSI
TIME - HOURS

FIG. 273

SECTION VII

SECTION 7.3.6 STRESS RUPTURE

FIG. 274


Master Rupture Curve
Inconel 702 - 0.040 in. Sheet
Transverse
100
10
STRESS - KSI
40
42
44
46
48
50
52
54
56
58
60
62
T(25 + logt) x 10^{-3}

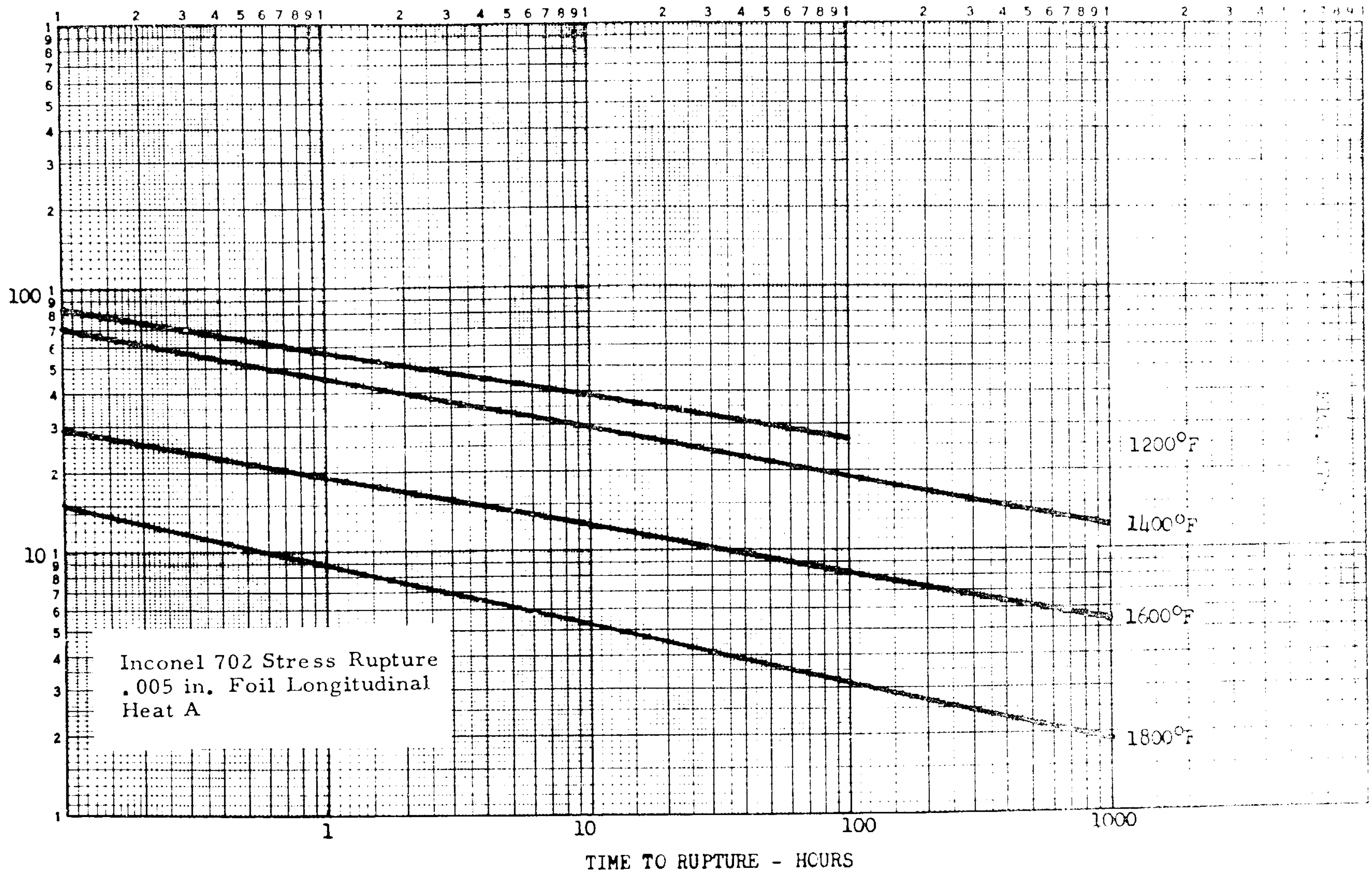
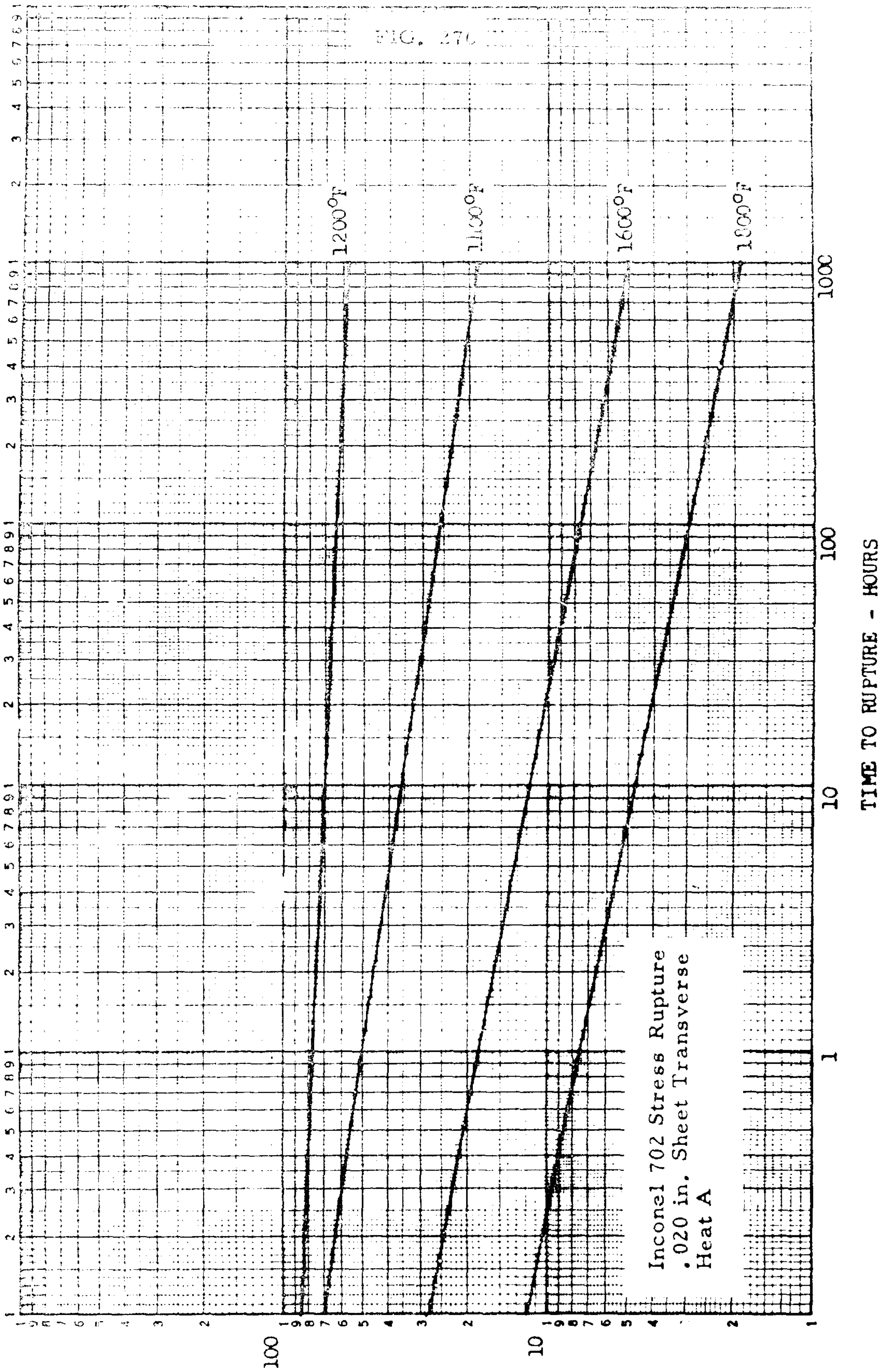


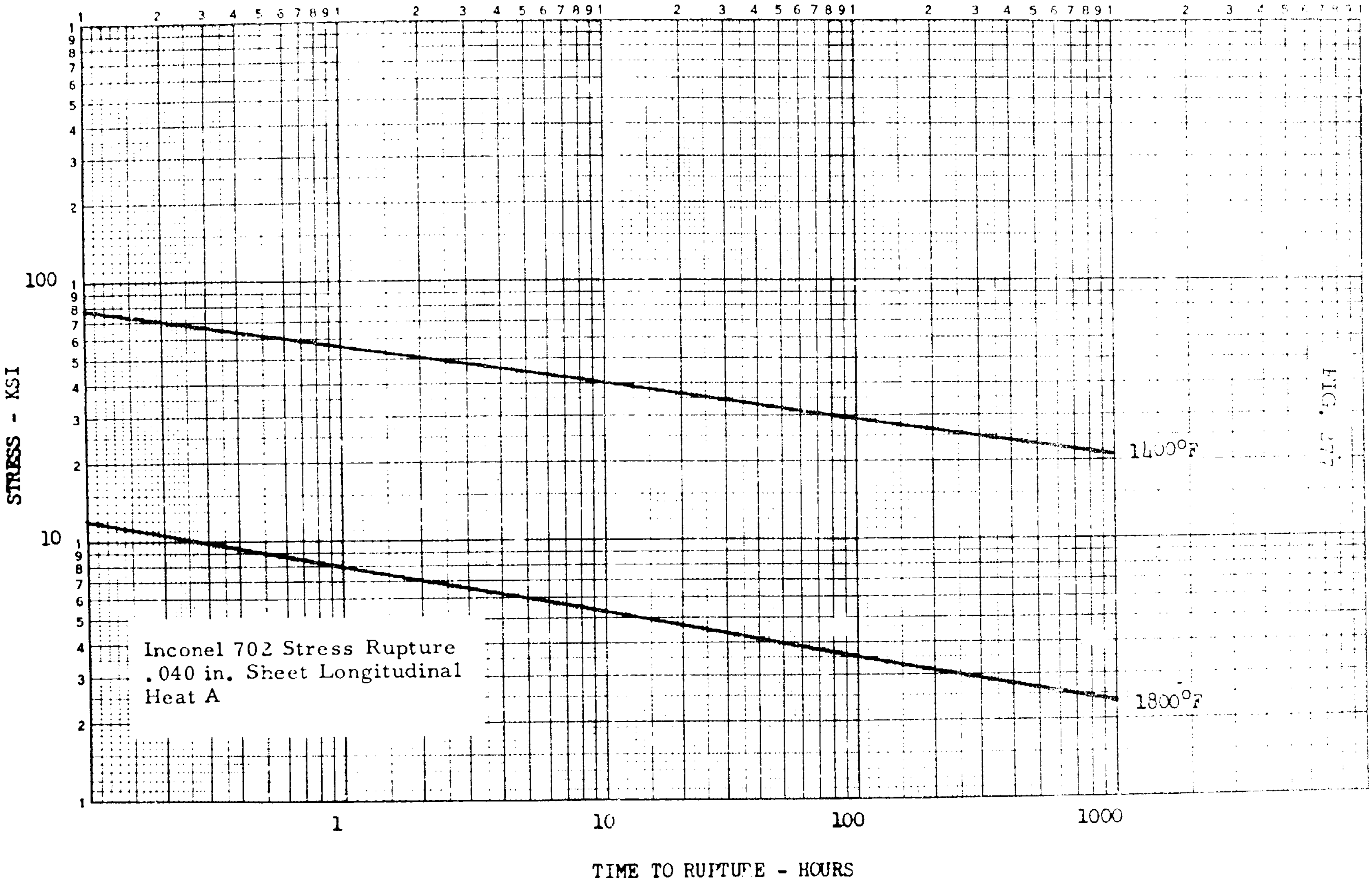
FIG. 279
Inconel 702 Stress Rupture
.005 in. Foil Longitudinal
Heat A
1200°F
1400°F
1600°F
1800°F
STRESS - KSI
TIME TO RUPTURE - HOURS

FIG. 270

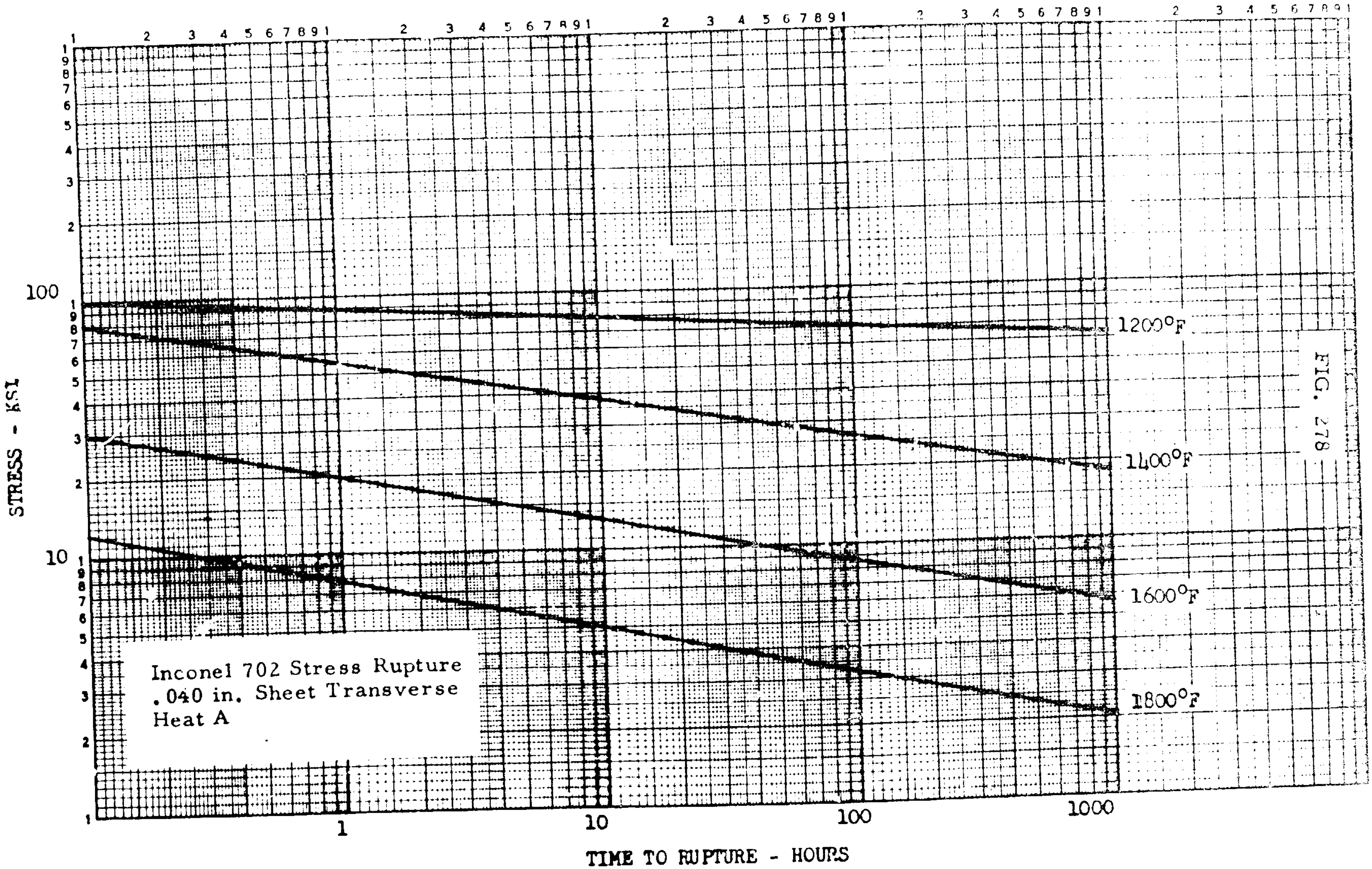


1200°F
1400°F
1600°F
1800°F
Inconel 702 Stress Rupture
.020 in. Sheet Transverse
Heat A
1
10
100
1000
TIME TO RUPTURE - HOURS
10
100

FIG. 277



Inconel 702 Stress Rupture
.040 in. Sheet Longitudinal
Heat A
1400°F
1800°F
STRESS - KSI
TIME TO RUPTURE - HOURS
100
10
1
10
100
1000



Inconel 702 Stress Rupture
.040 in. Sheet Transverse
Heat A
1200°F
1400°F
1600°F
1800°F
STRESS - KSI
100
10
TIME TO RUPTURE - HOURS
1
10
100
1000

FIG. 278

SECTION VII

FATIGUE

SECTION 7.3.7

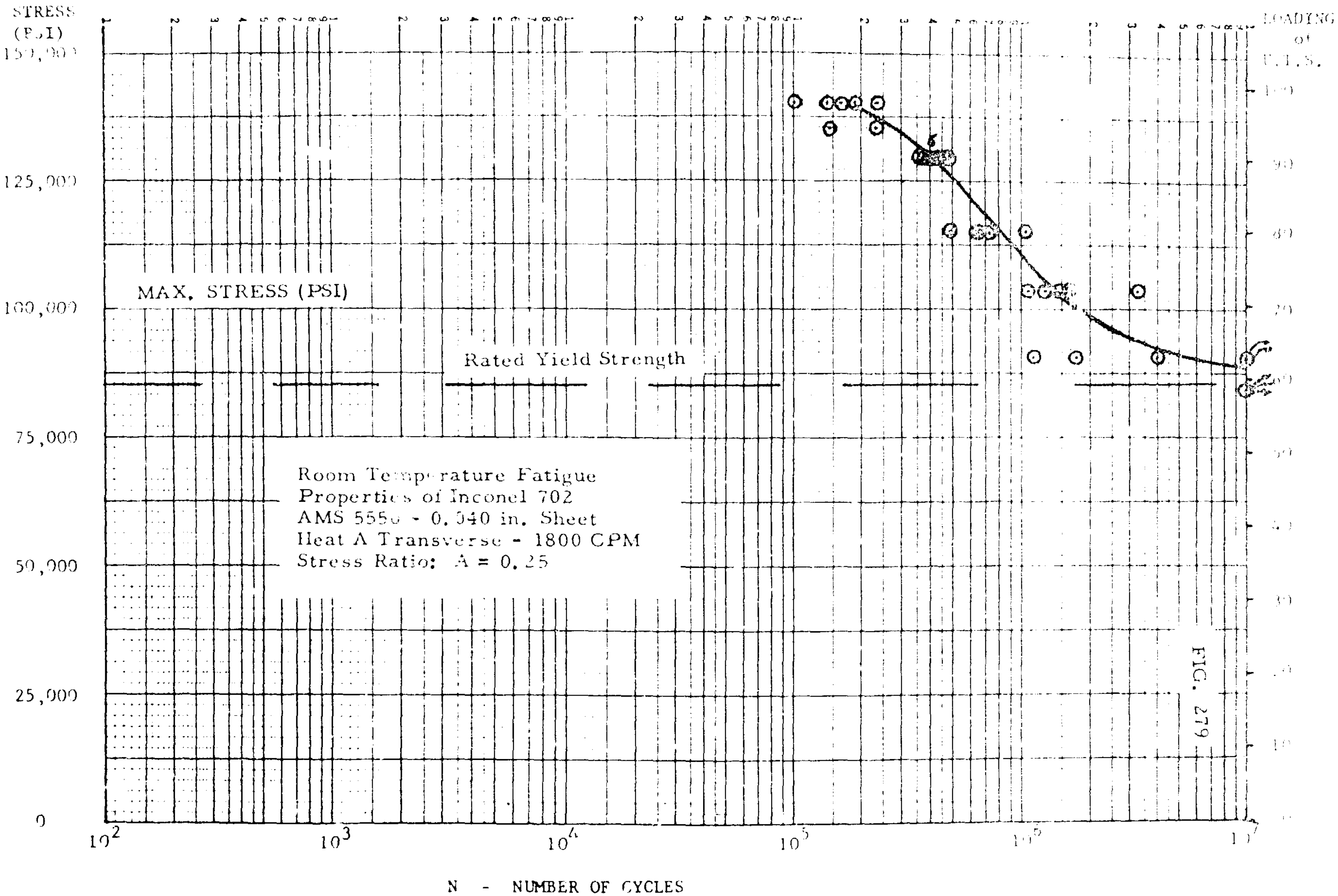
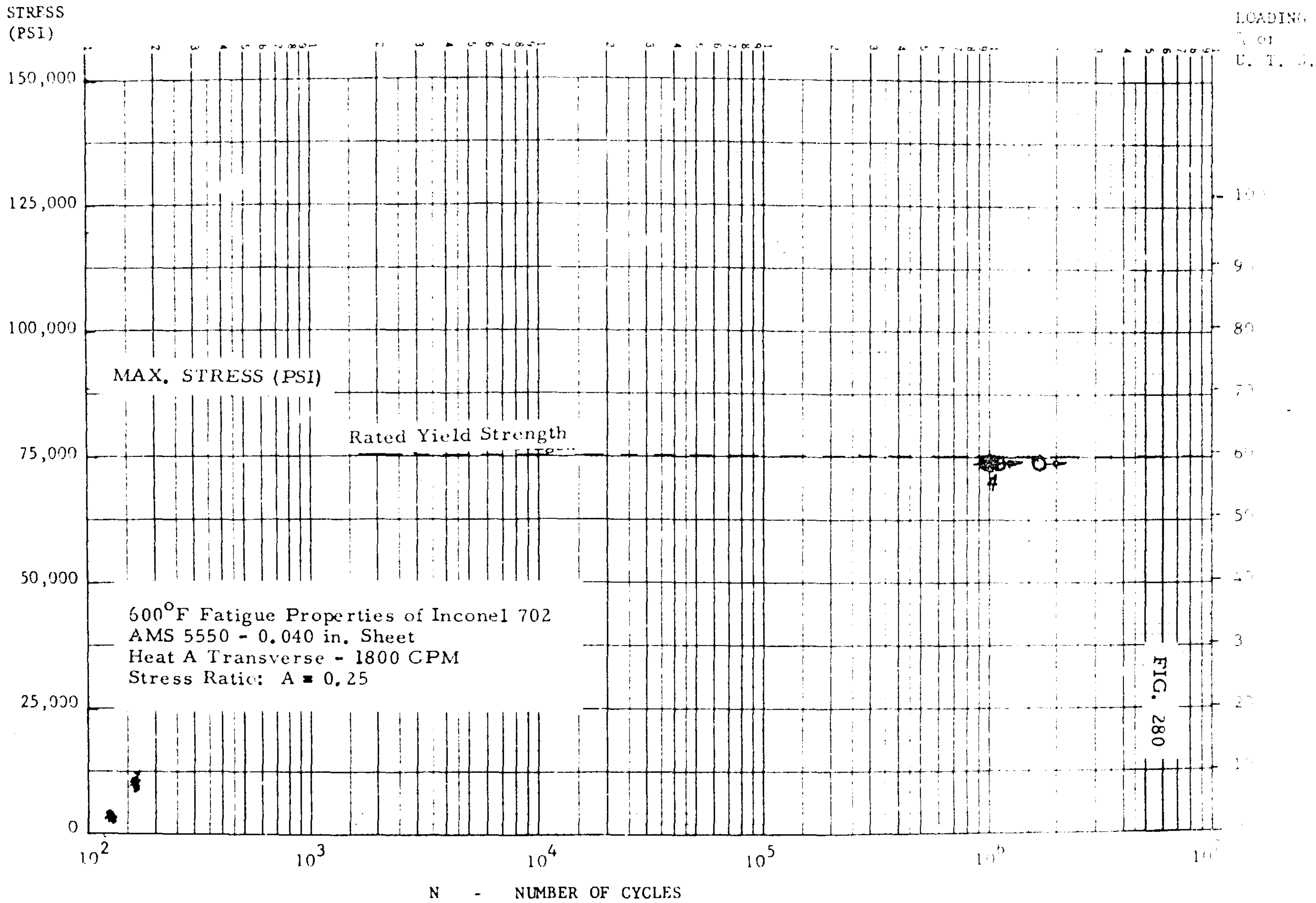

STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING of U.T.S.
MAX. STRESS (PSI)
Rated Yield Strength
Room Temperature Fatigue
Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 279


STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING % of U. T. S.
MAX. STRESS (PSI)
Rated Yield Strength
600°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
FIG. 280
10^2
10^3
10^4
10^5
N - NUMBER OF CYCLES

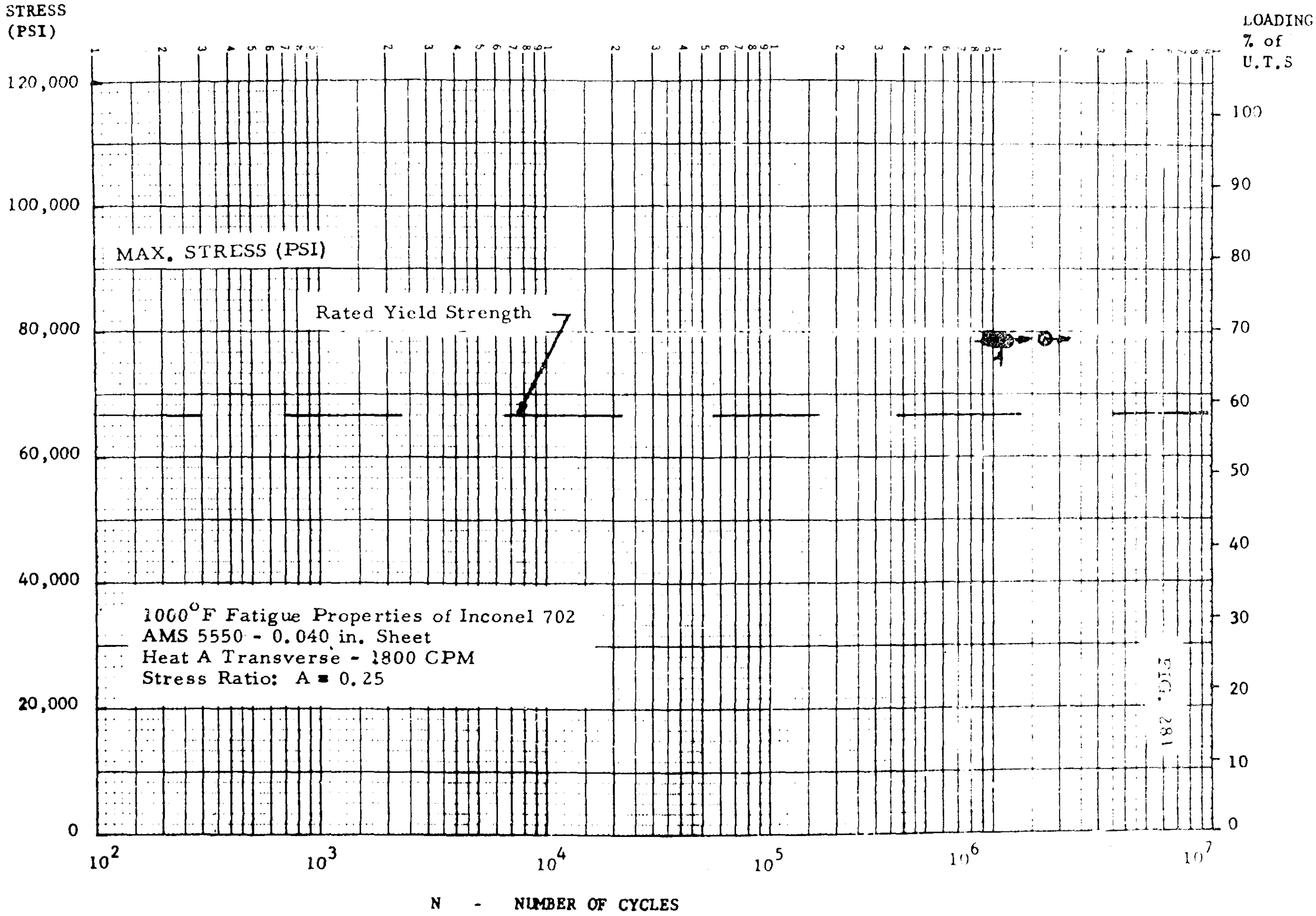
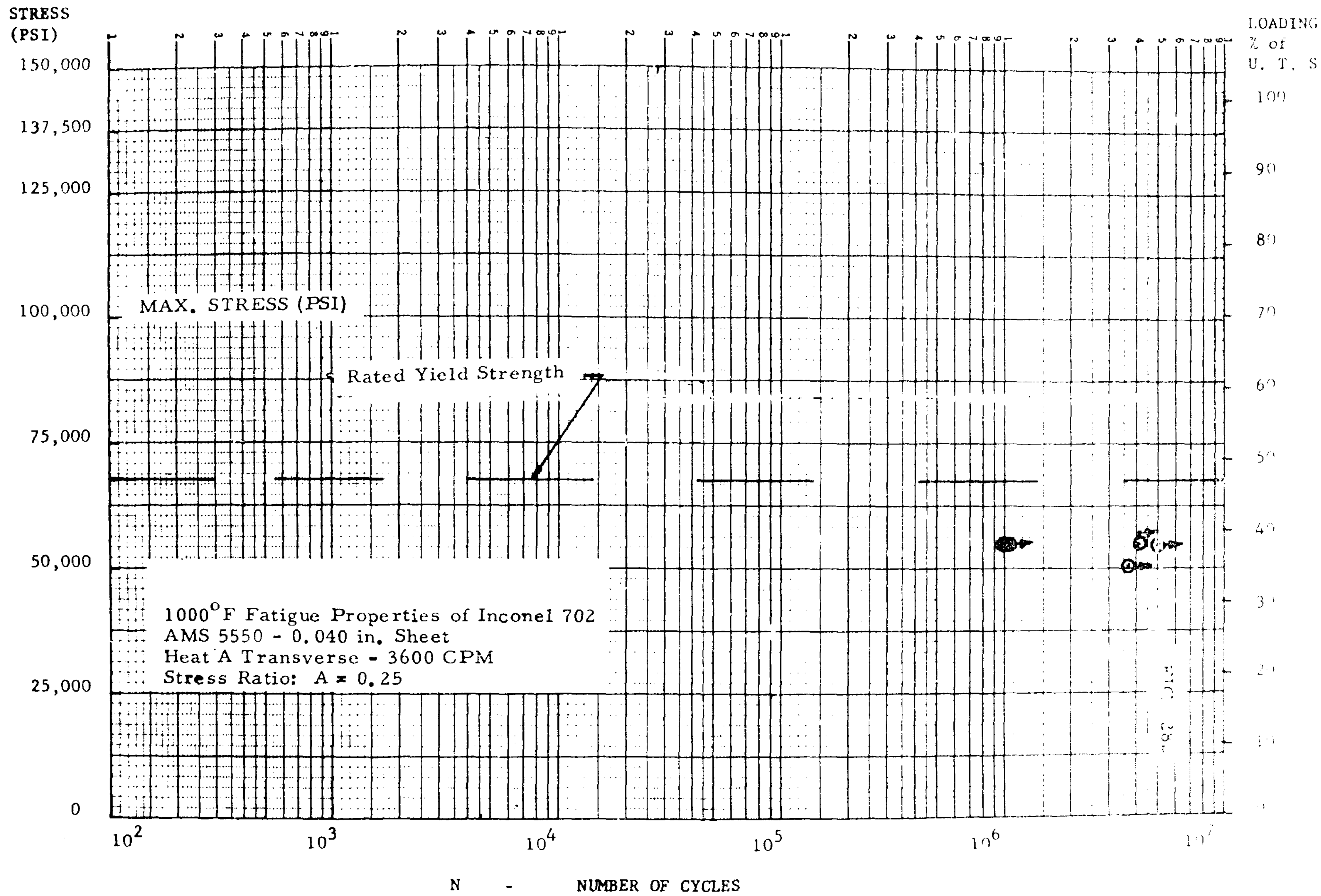
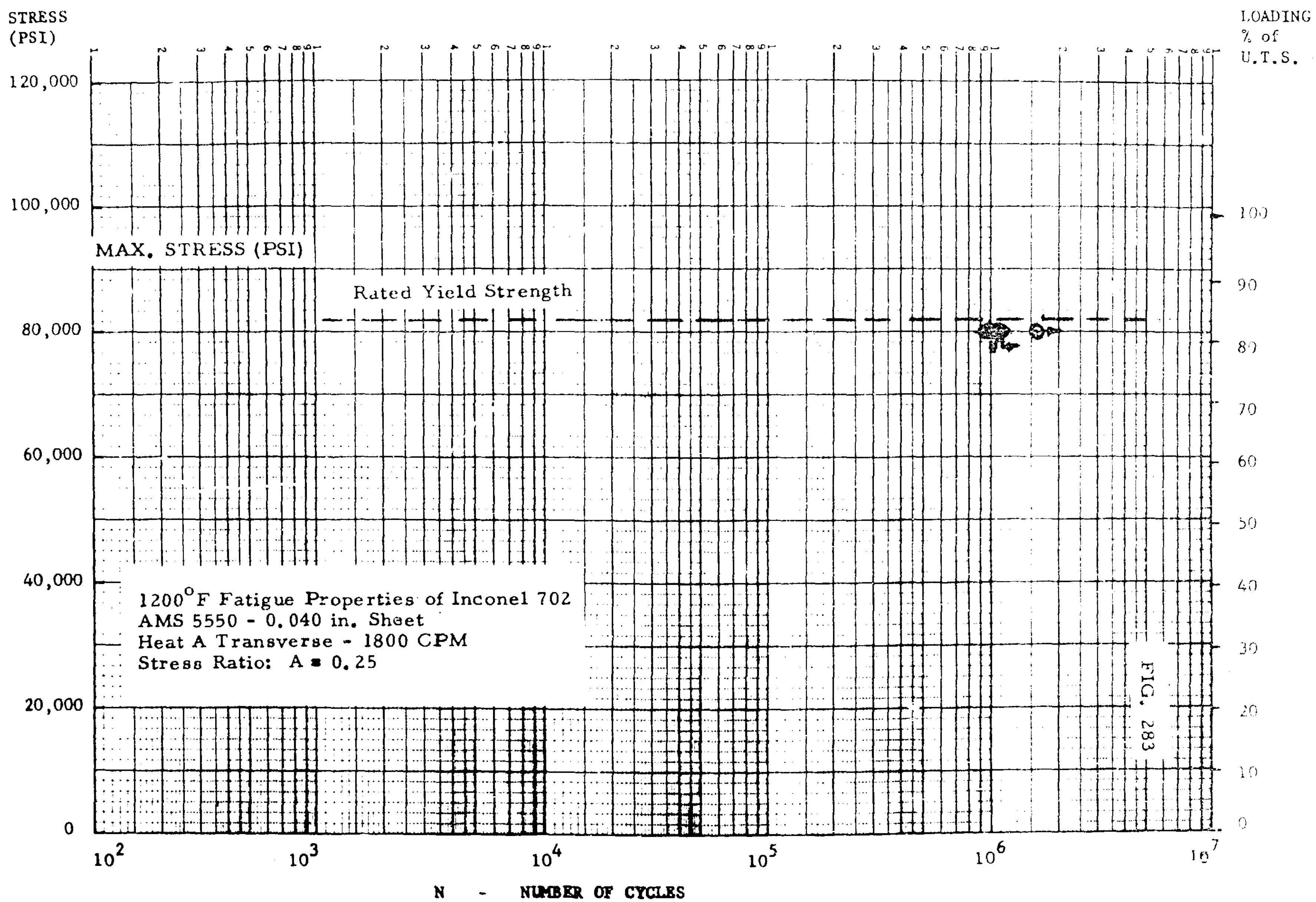

STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
LOADING % of U.T.S
100
90
80
70
60
50
40
30
20
10
0
MAX. STRESS (PSI)
Rated Yield Strength
1000°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 281


STRESS (PSI)
150,000
137,500
125,000
100,000
75,000
50,000
25,000
0
MAX. STRESS (PSI)
Rated Yield Strength
1000°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 3600 CPM
Stress Ratio: A = 0.25
LOADING % of U. T. S.
N - NUMBER OF CYCLES



STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
MAX. STRESS (PSI)
Rated Yield Strength
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES
$1200^{\circ}F$ Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25

FIG. 283

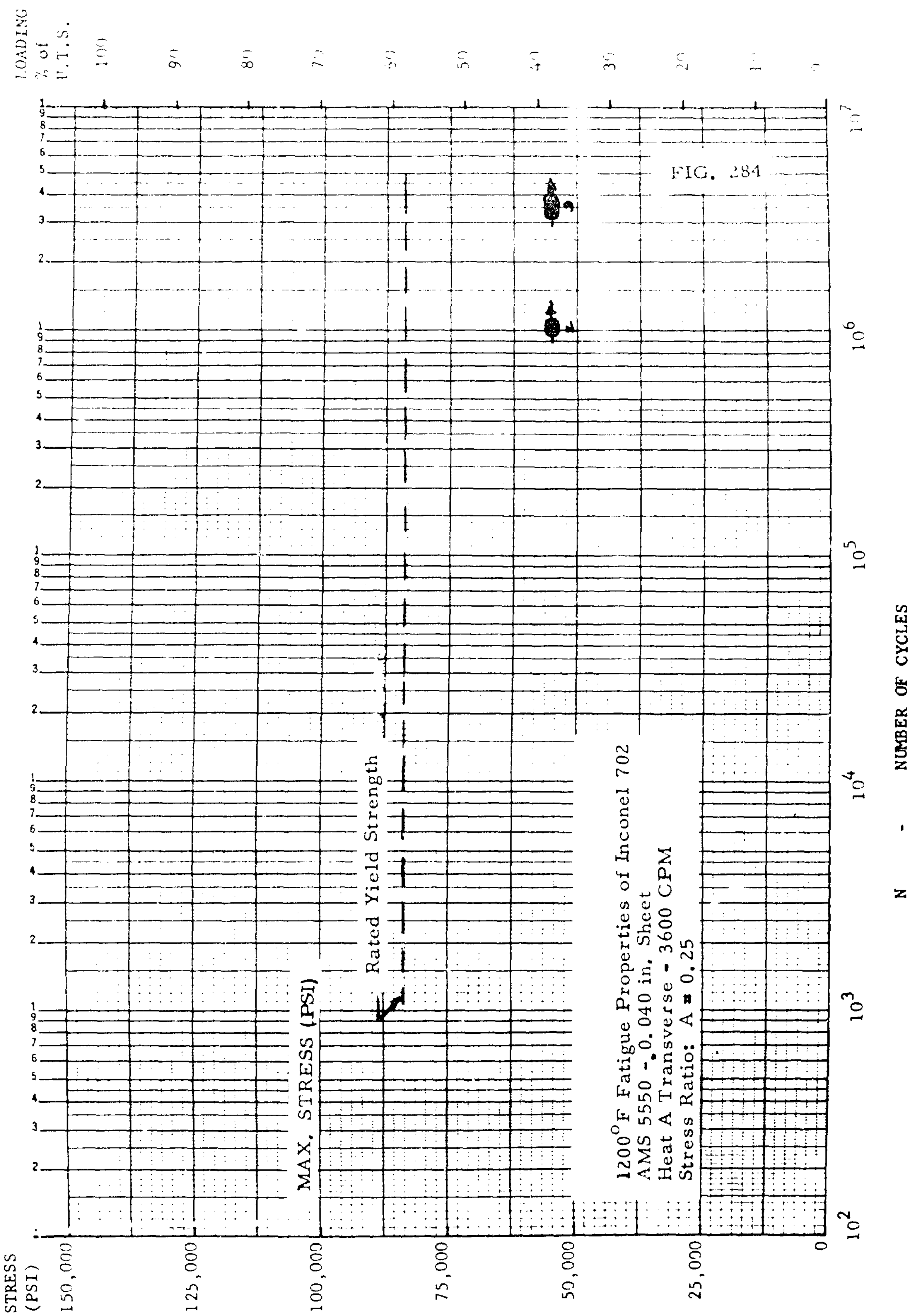


FIG. 284
1200°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 3600 CPM
Stress Ratio: A = 0.25
Rated Yield Strength
MAX. STRESS (PSI)
STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
N - NUMBER OF CYCLES
10^2
10^3
10^4
10^5
10^6
10^7

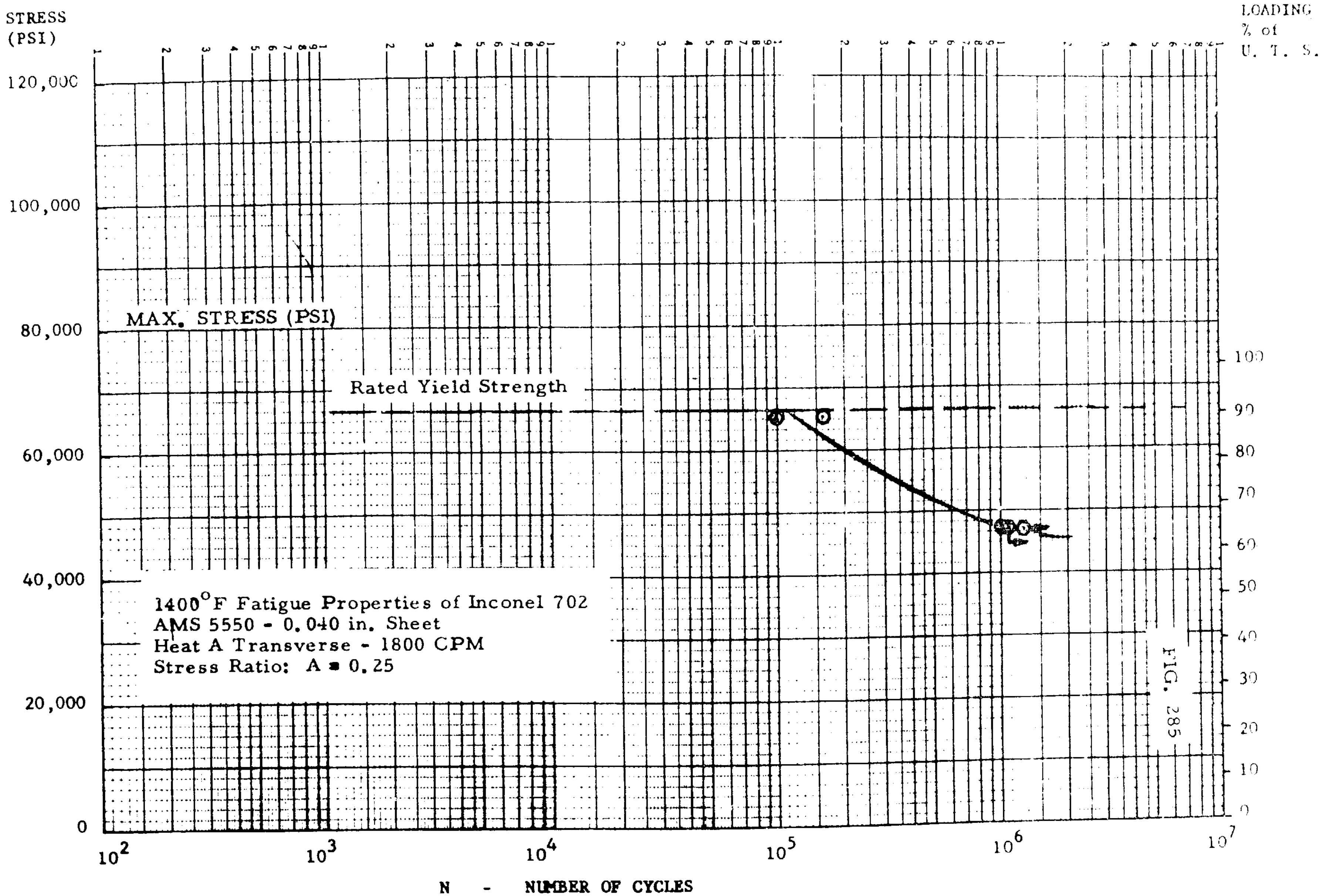

STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
MAX. STRESS (PSI)
Rated Yield Strength
1400°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
LOADING % of U. T. S.
100
90
80
70
60
50
40
30
20
10
0
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 285

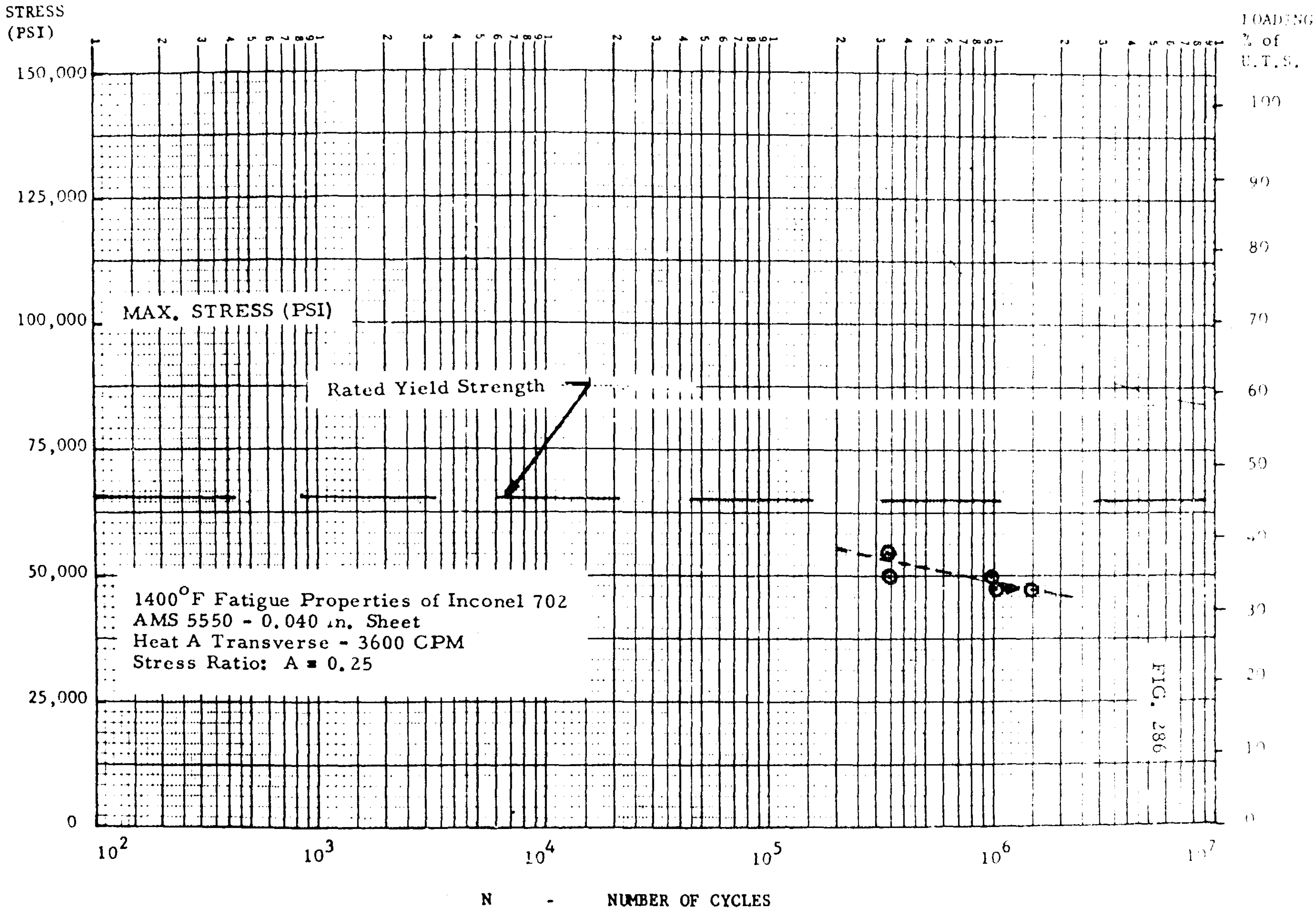
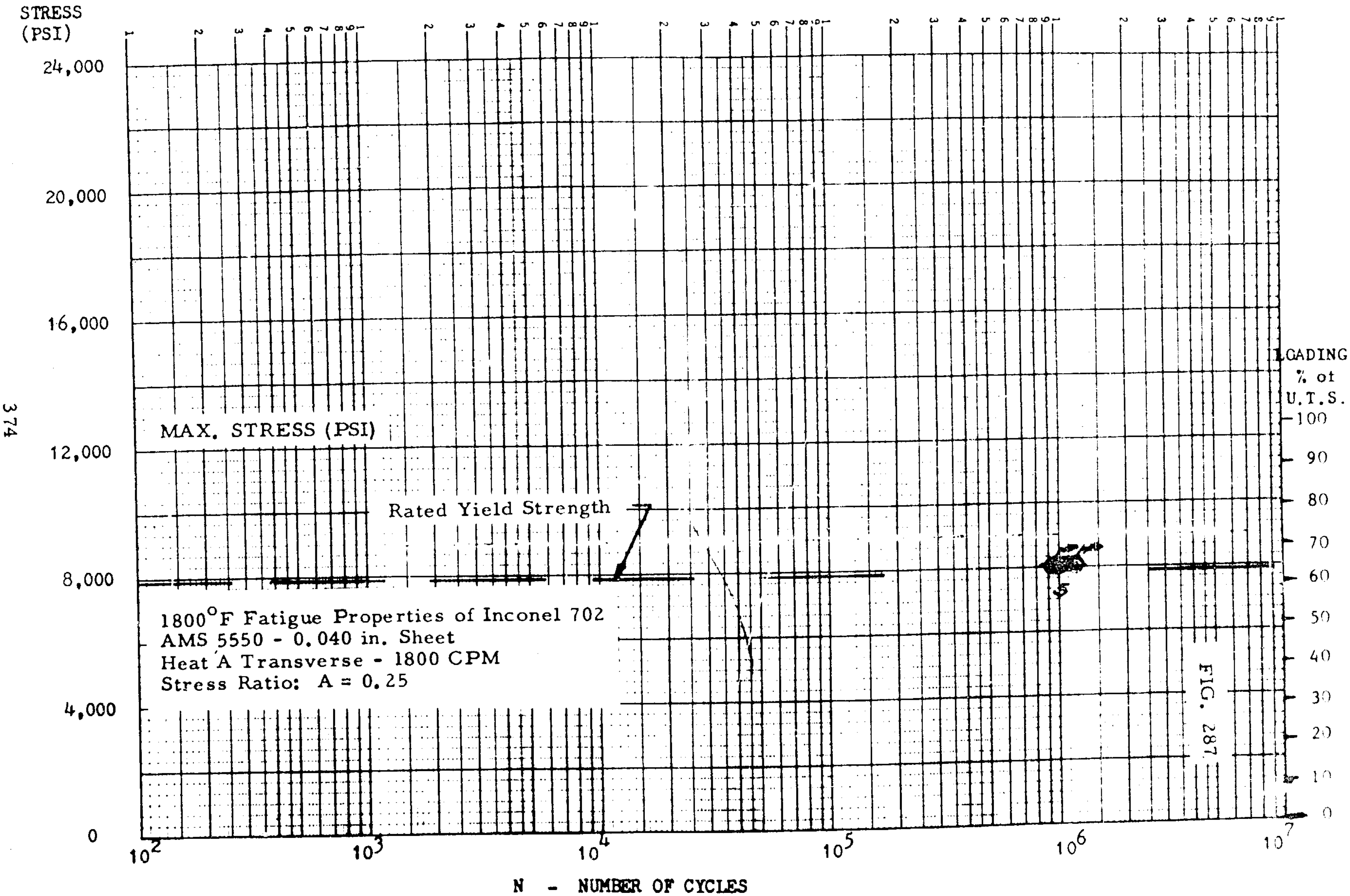

STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
MAX. STRESS (PSI)
Rated Yield Strength
1400°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 3600 CPM
Stress Ratio: A = 0.25
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 286



STRESS (PSI)
24,000
20,000
16,000
12,000
8,000
4,000
0
MAX. STRESS (PSI)
Rated Yield Strength
1800°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.25
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 287

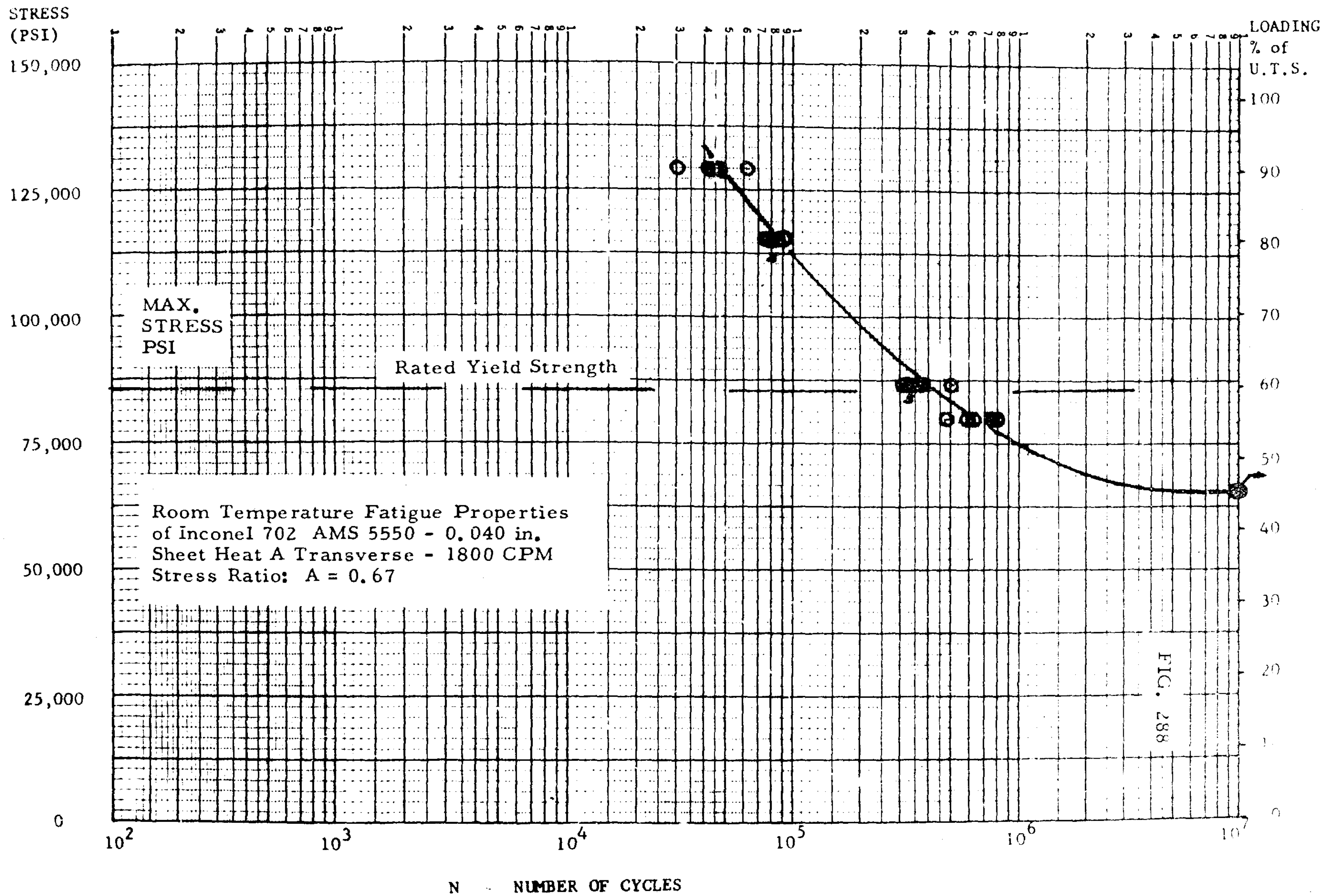

STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
0
MAX. STRESS PSI
Rated Yield Strength
Room Temperature Fatigue Properties
of Inconel 702 AMS 5550 - 0.040 in.
Sheet Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 288

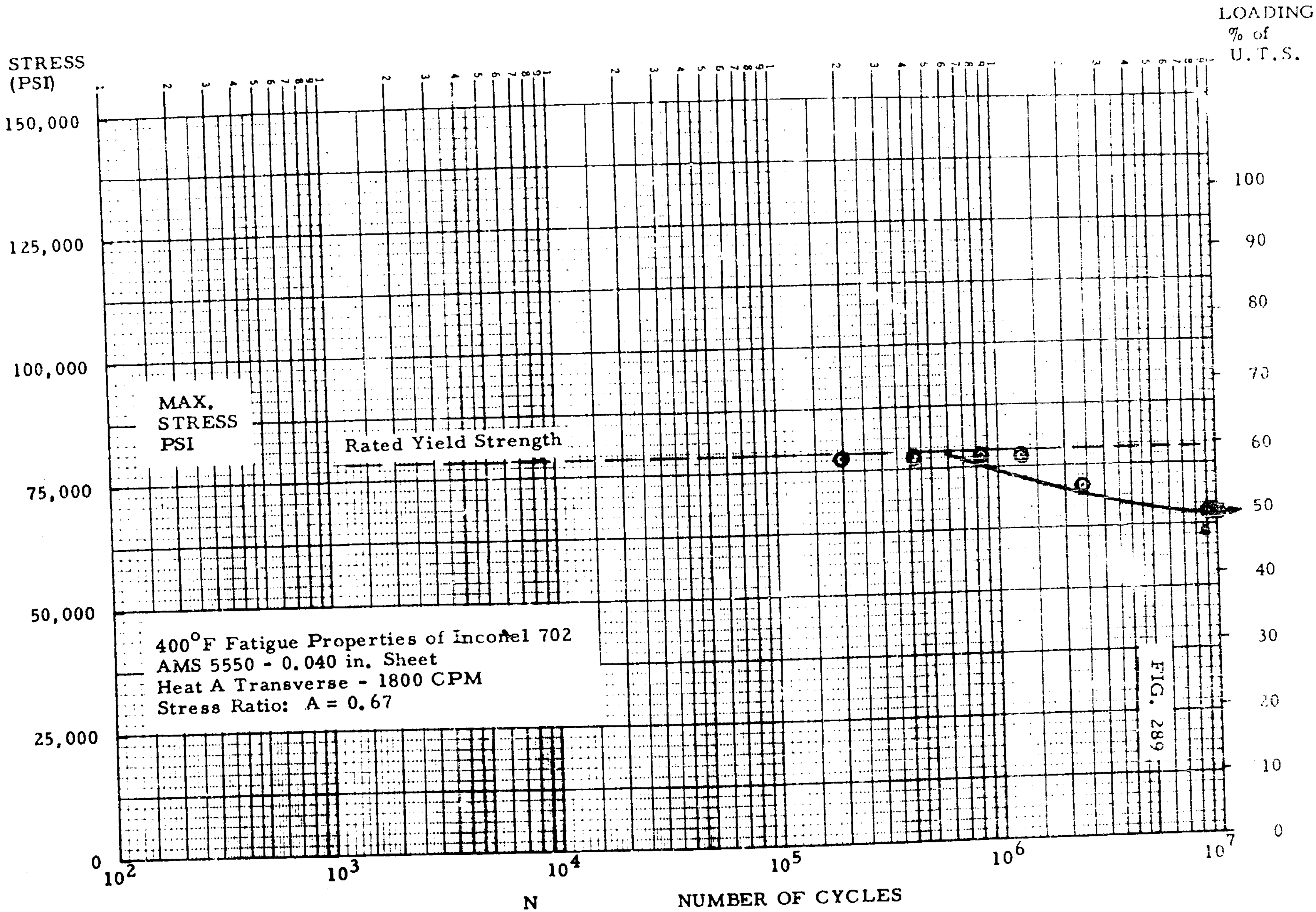
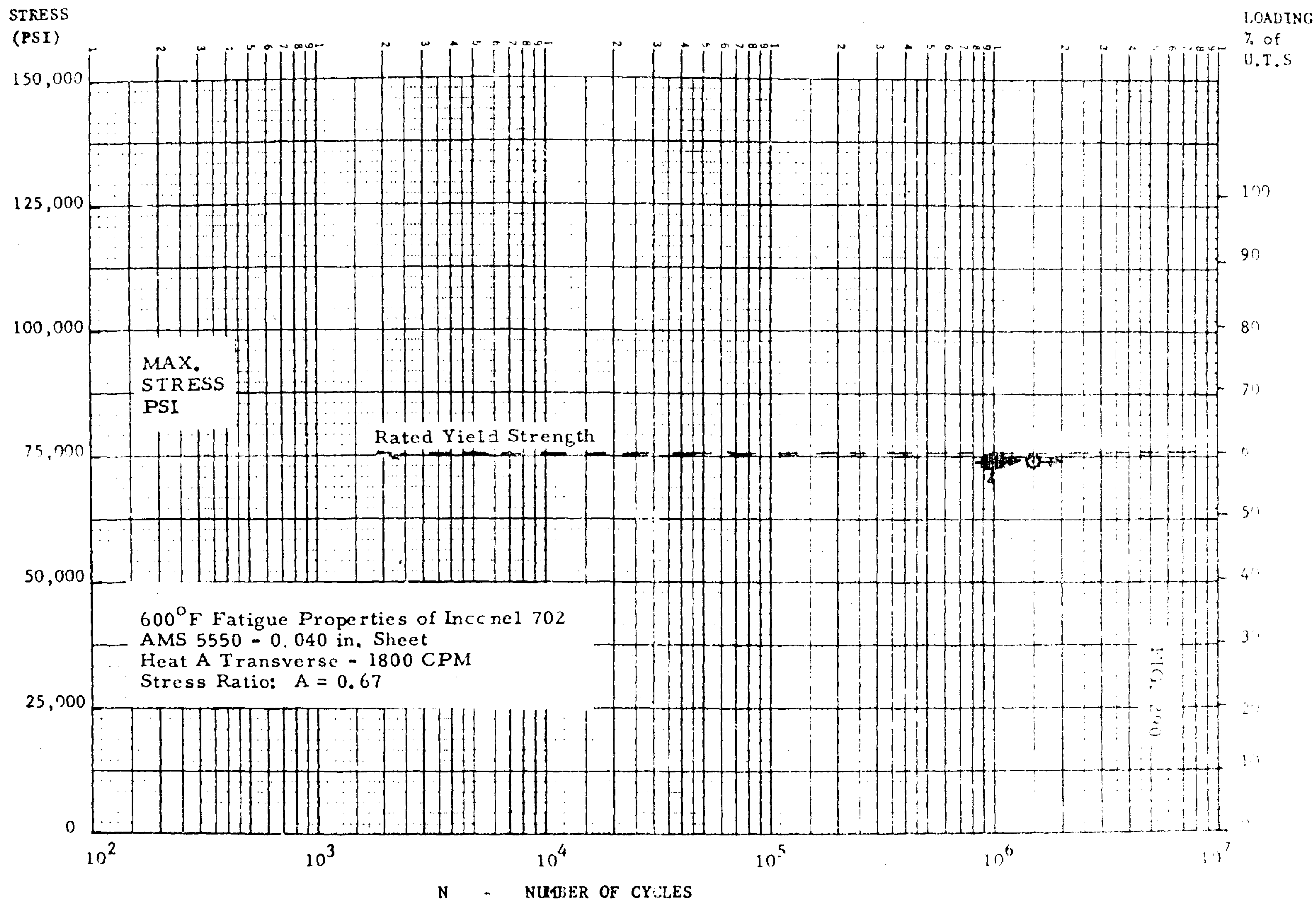
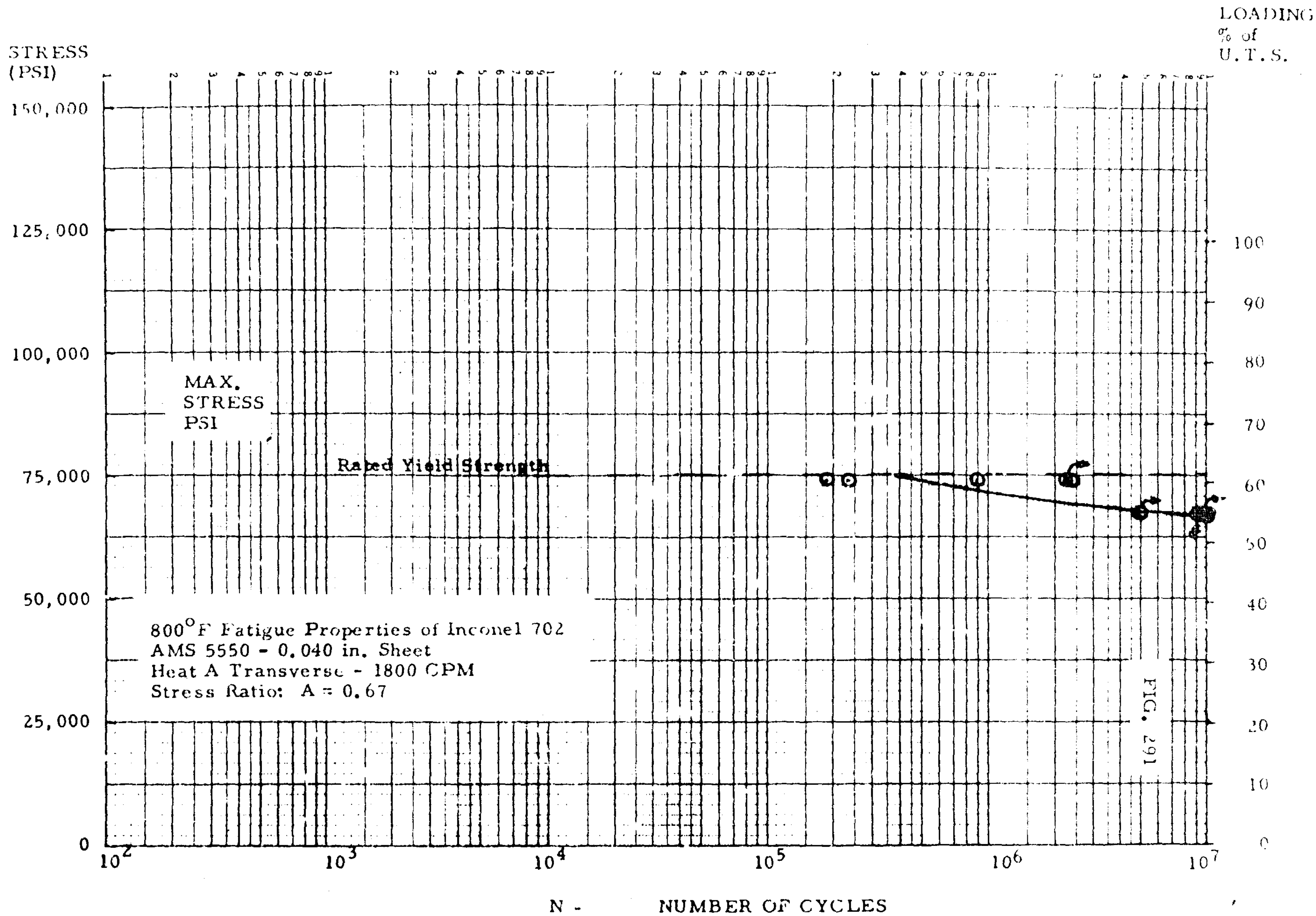

STRESS (PSI)
LOADING % of U.T.S.
MAX. STRESS PSI
Rated Yield Strength
400°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
N
NUMBER OF CYCLES

FIG. 289


STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING % of U.T.S
100
90
80
70
50
MAX. STRESS PSI
Rated Yield Strength
600°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
FIG. 290
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES



STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
MAX. STRESS PSI
Rated Yield Strength
800°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 291

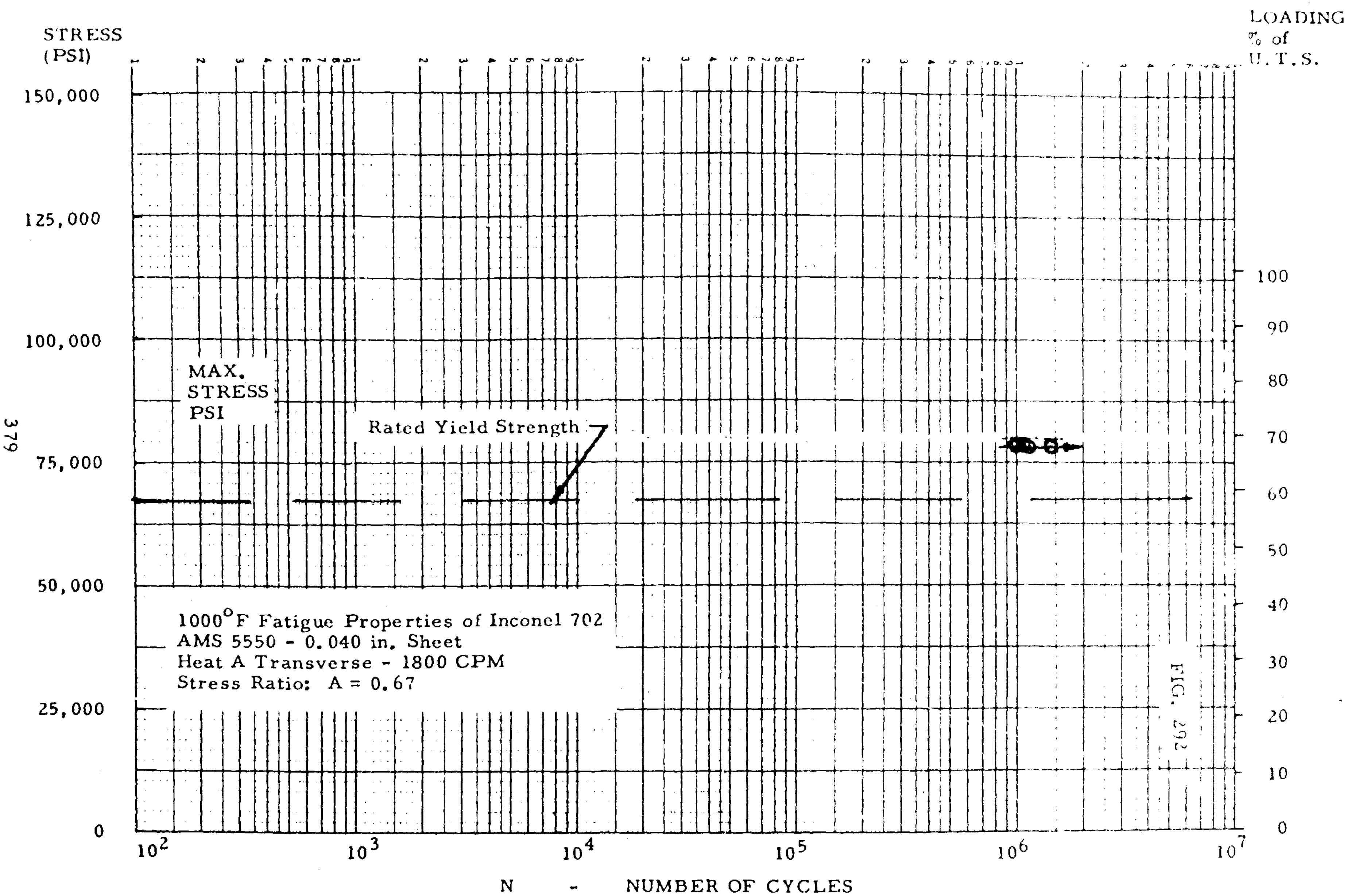

STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
MAX. STRESS PSI
Rated Yield Strength
1000°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 292

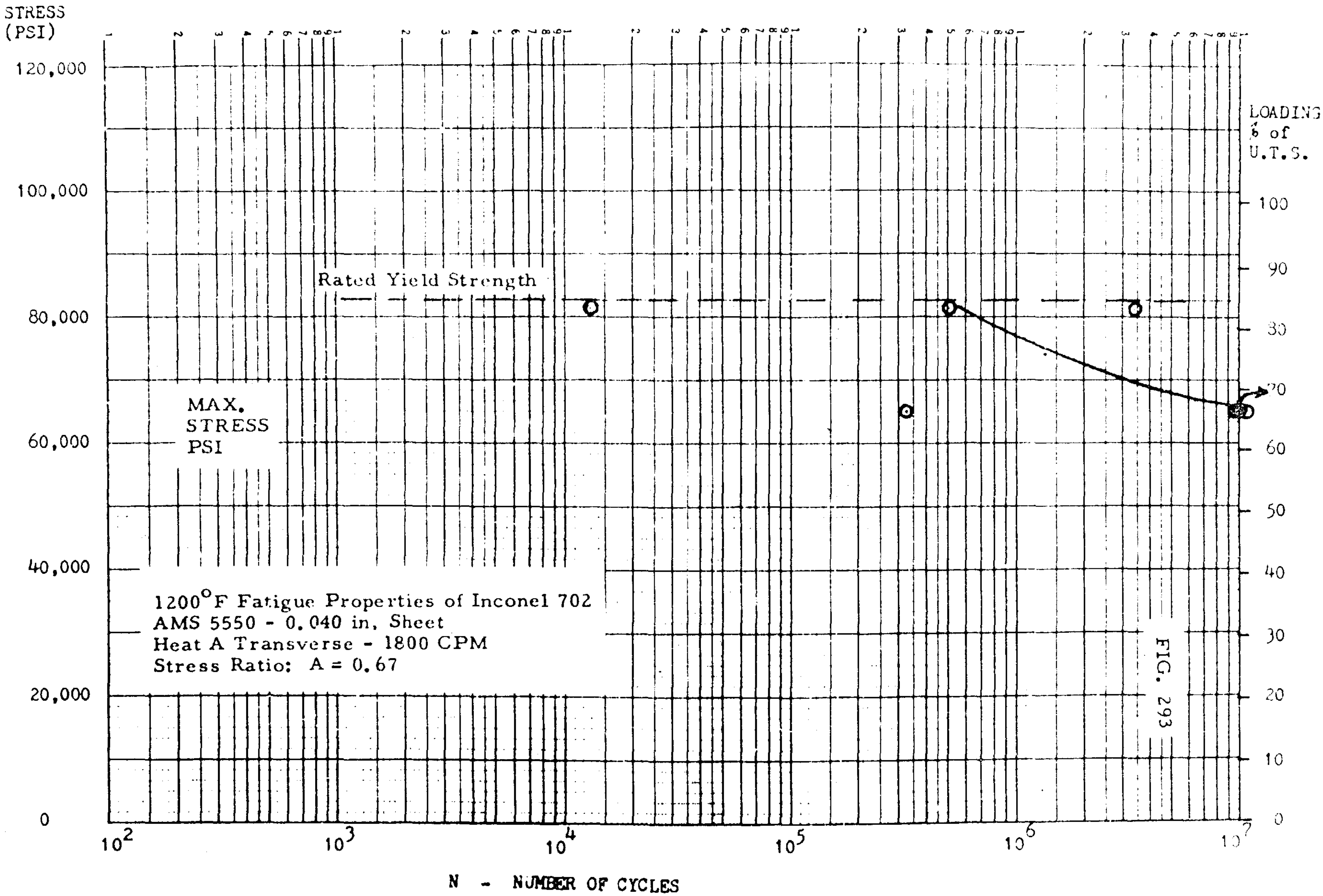

STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
1200°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
N - NUMBER OF CYCLES

FIG. 293

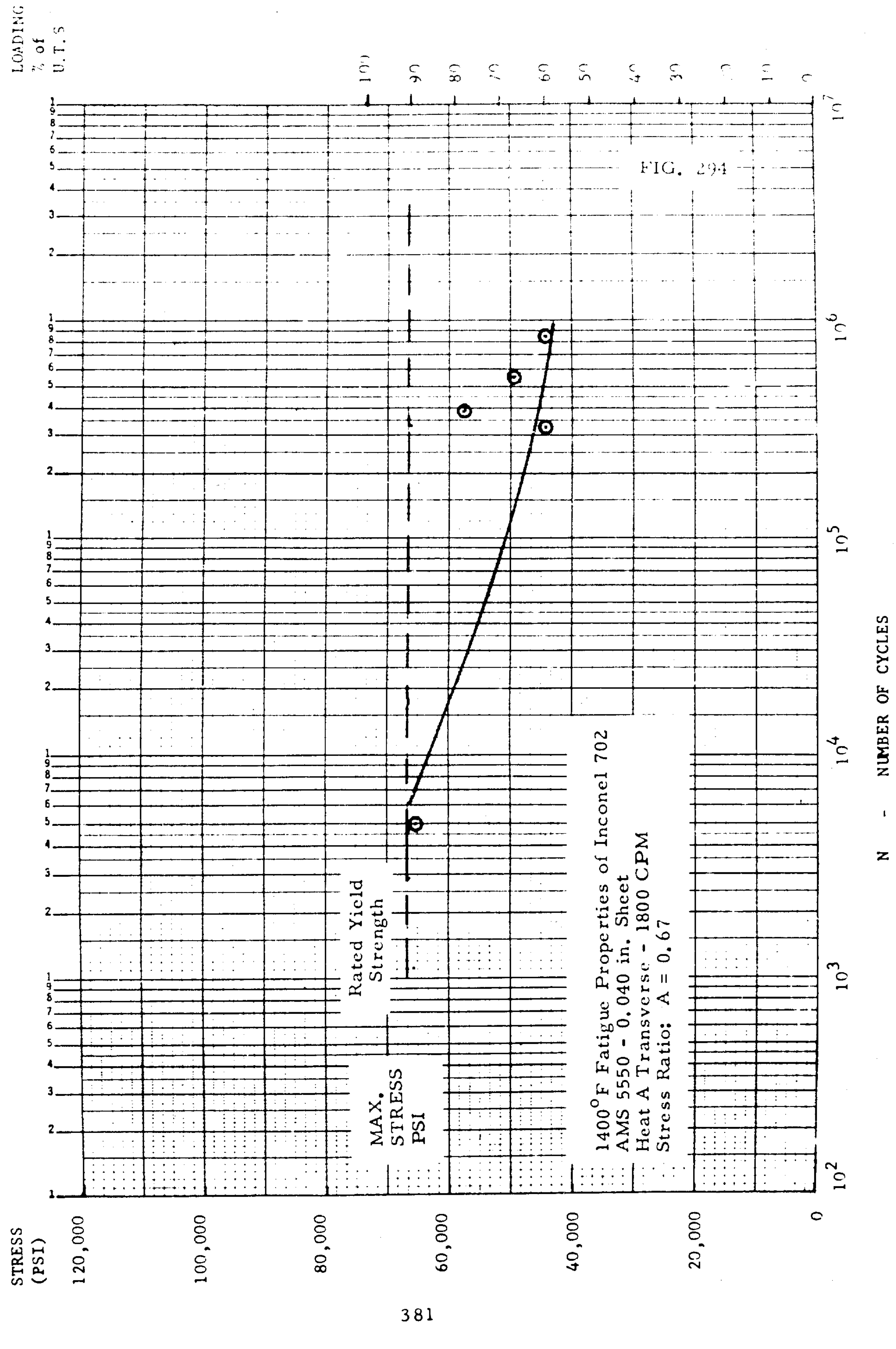
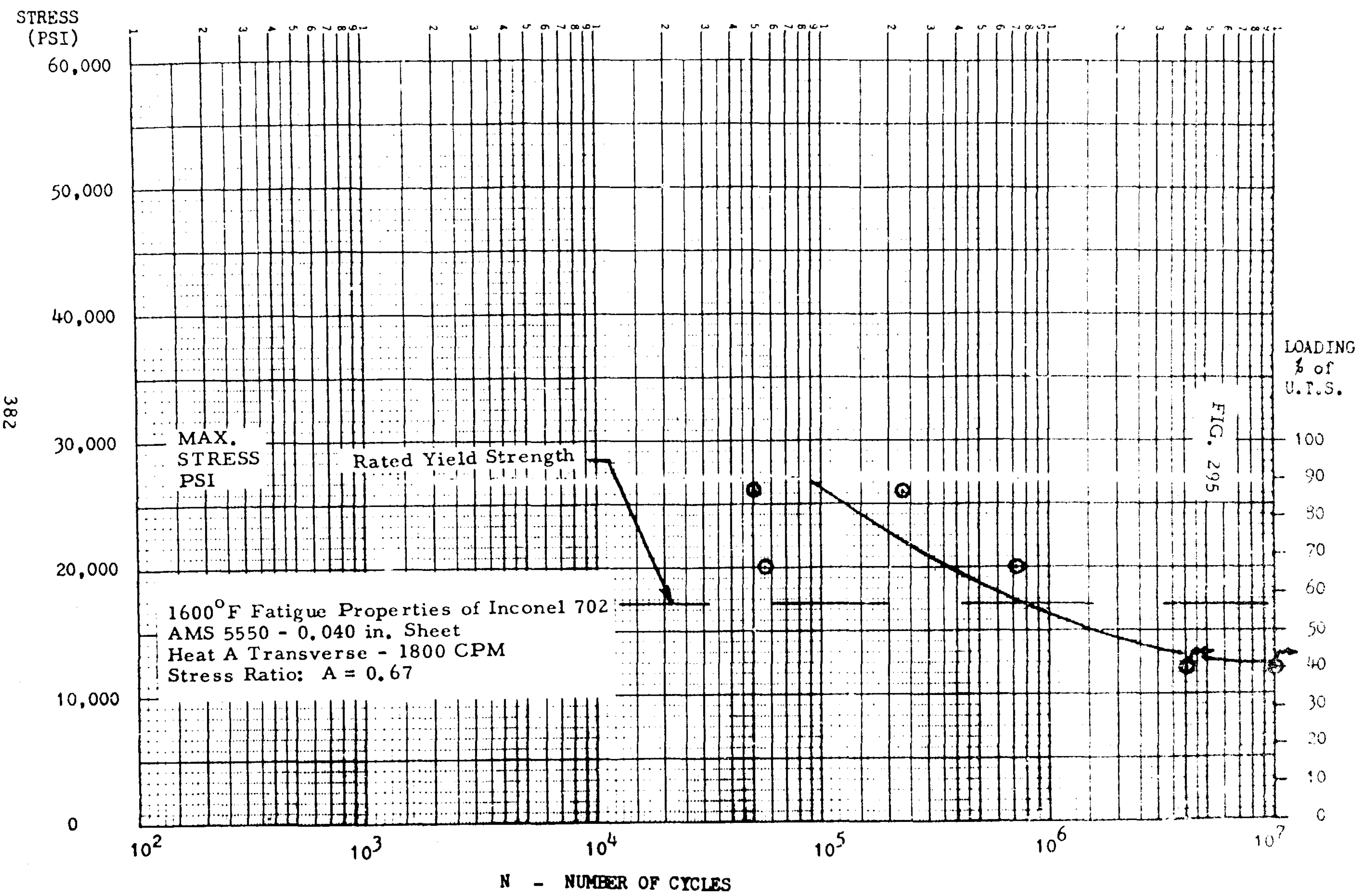


FIG. 294
1400°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
Rated Yield Strength
MAX. STRESS PSI
LOADING % of U.T.S
STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
N - NUMBER OF CYCLES
10^2
10^3
10^4
10^5
10^6
10^7

FIG. 295


STRESS (PSI)
60,000
50,000
40,000
30,000
20,000
10,000
0
MAX. STRESS PSI
Rated Yield Strength
1600°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

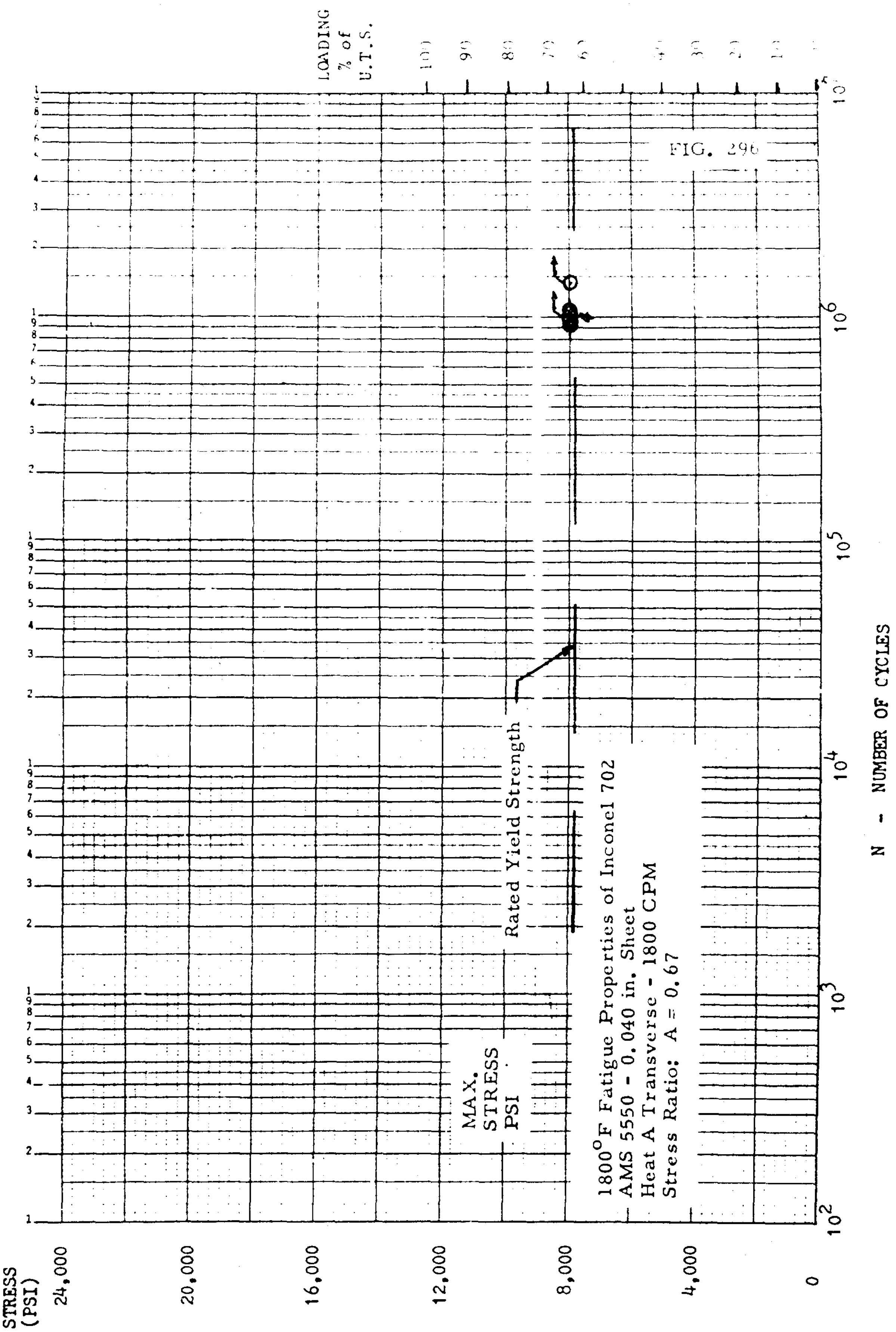


FIG. 296
1800°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.67
Rated Yield Strength
MAX. STRESS PSI
LOADING % of U.T.S.
STRESS (PSI)
24,000
20,000
16,000
12,000
8,000
4,000
0
N - NUMBER OF CYCLES
10^2
10^3
10^4
10^5
10^6
10^7

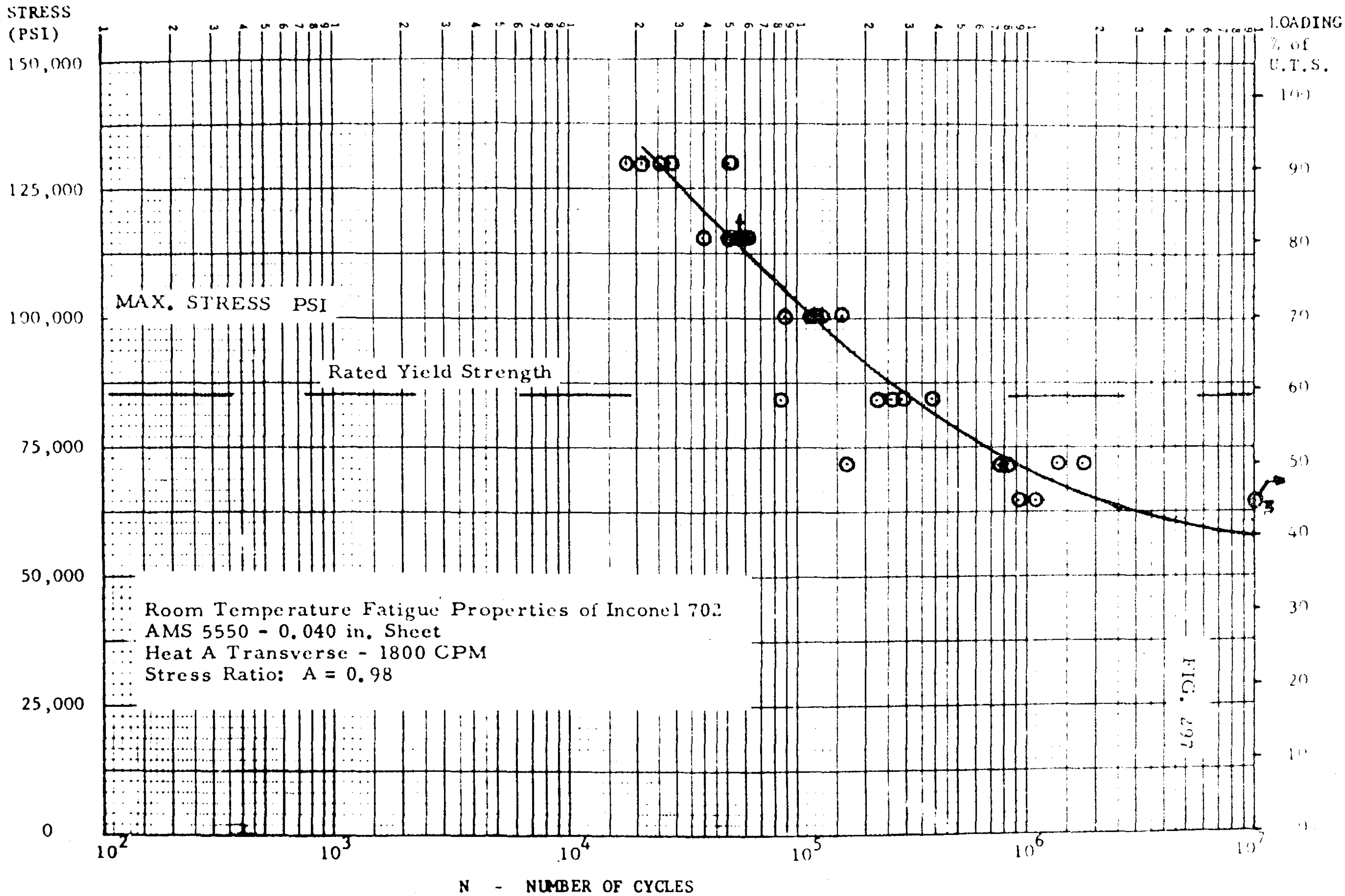

STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
MAX. STRESS PSI
Rated Yield Strength
Room Temperature Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 297

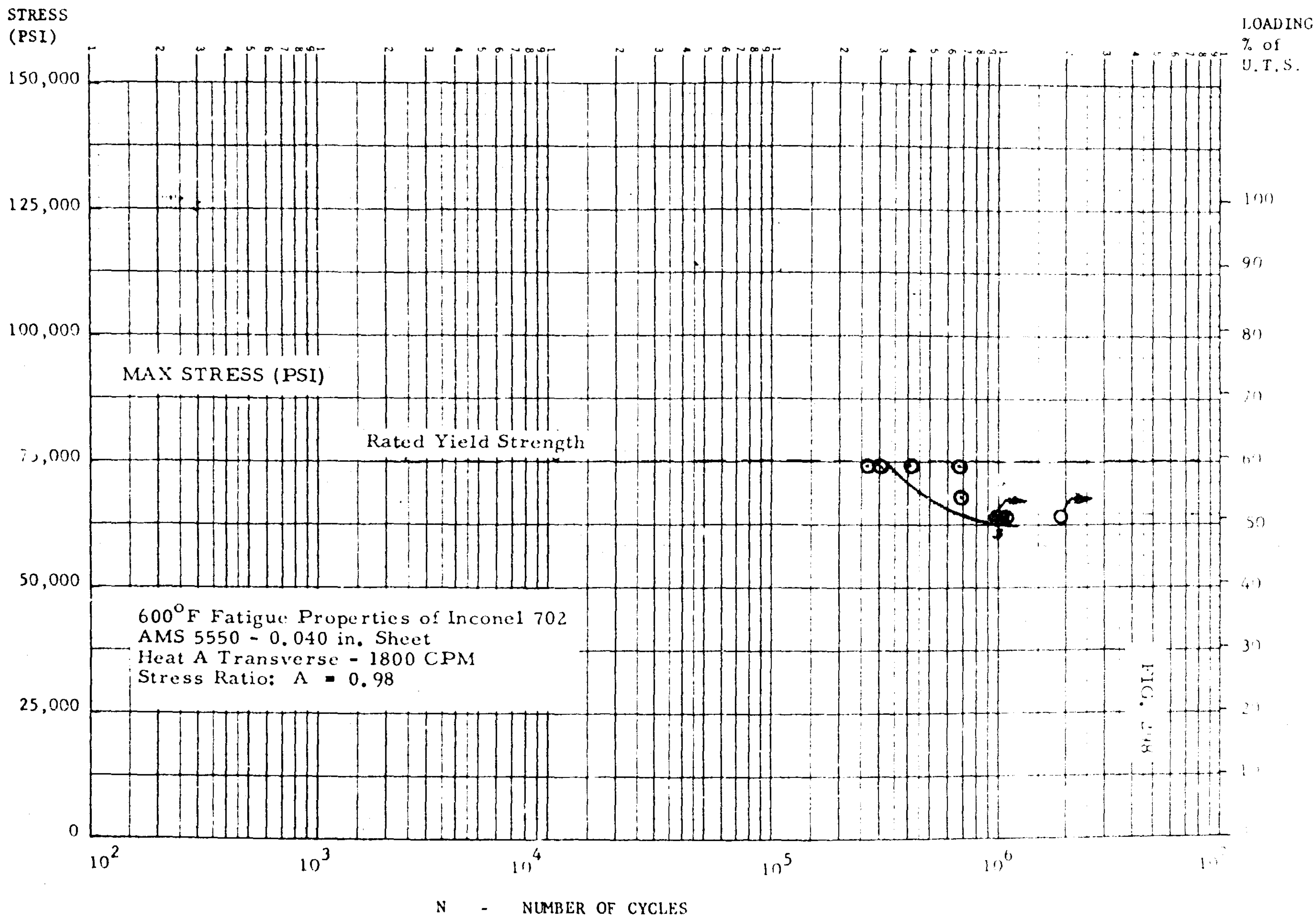
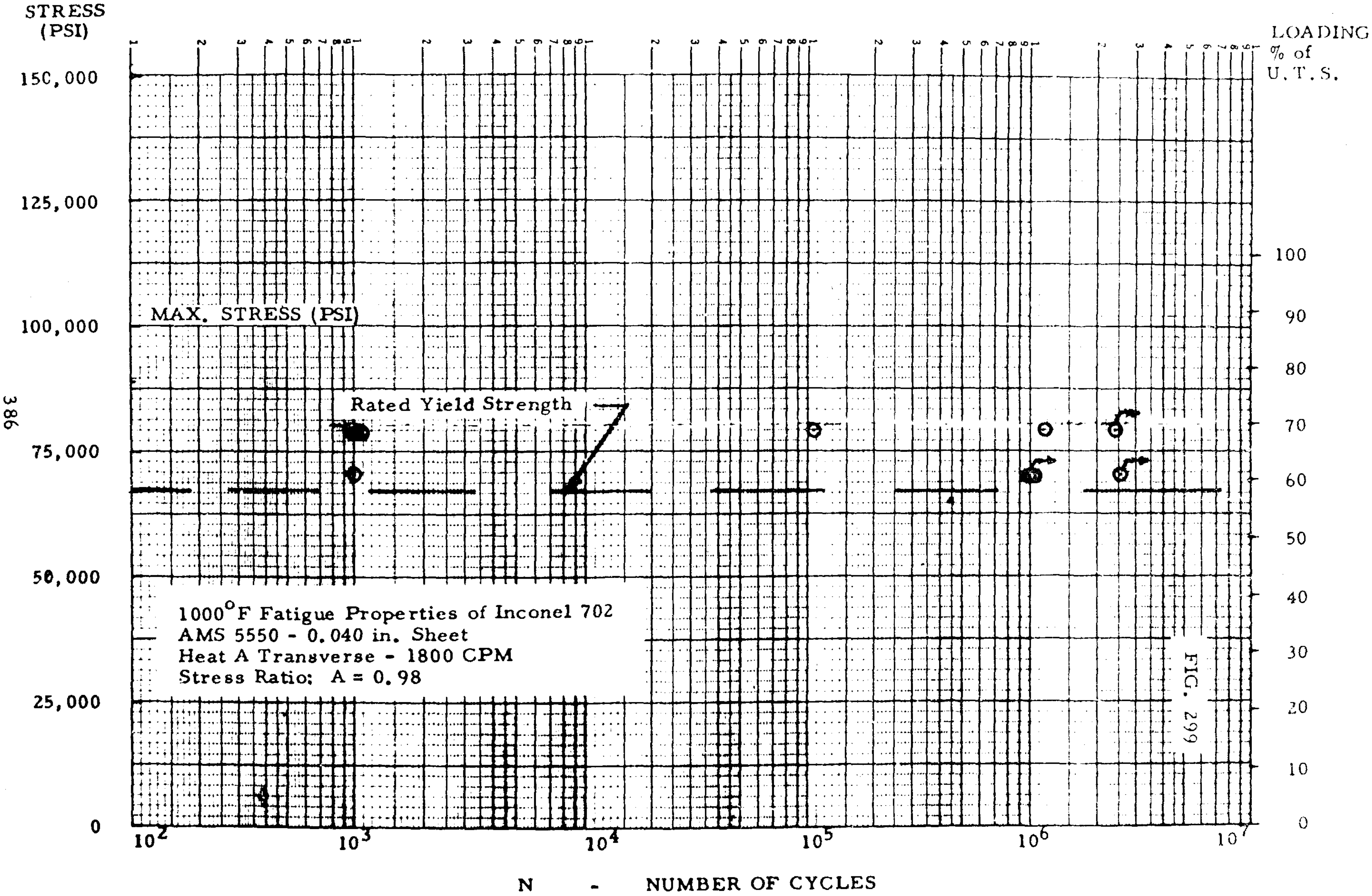
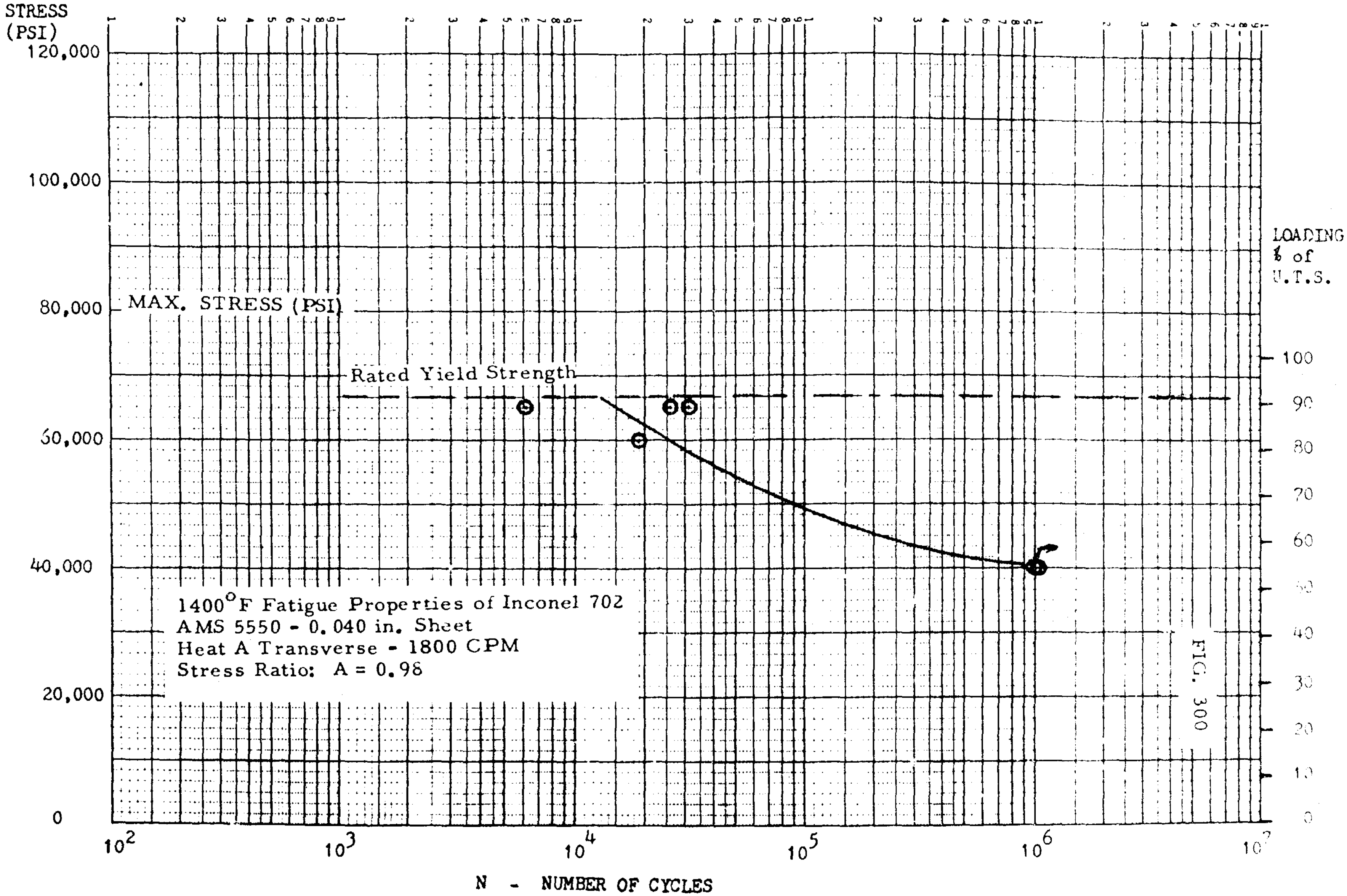

STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
MAX STRESS (PSI)
Rated Yield Strength
600°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
10^2
10^3
10^4
10^5
10^6
N - NUMBER OF CYCLES

FIG. 298



STRESS (PSI)
150,000
125,000
100,000
75,000
50,000
25,000
0
MAX. STRESS (PSI)
Rated Yield Strength
1000°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 299


STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
MAX. STRESS (PSI)
Rated Yield Strength
LOADING % of U.T.S.
100
90
80
70
60
40
30
20
0
1400°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
FIG. 300
10^2
10^3
10^4
10^5
10^6
N - NUMBER OF CYCLES

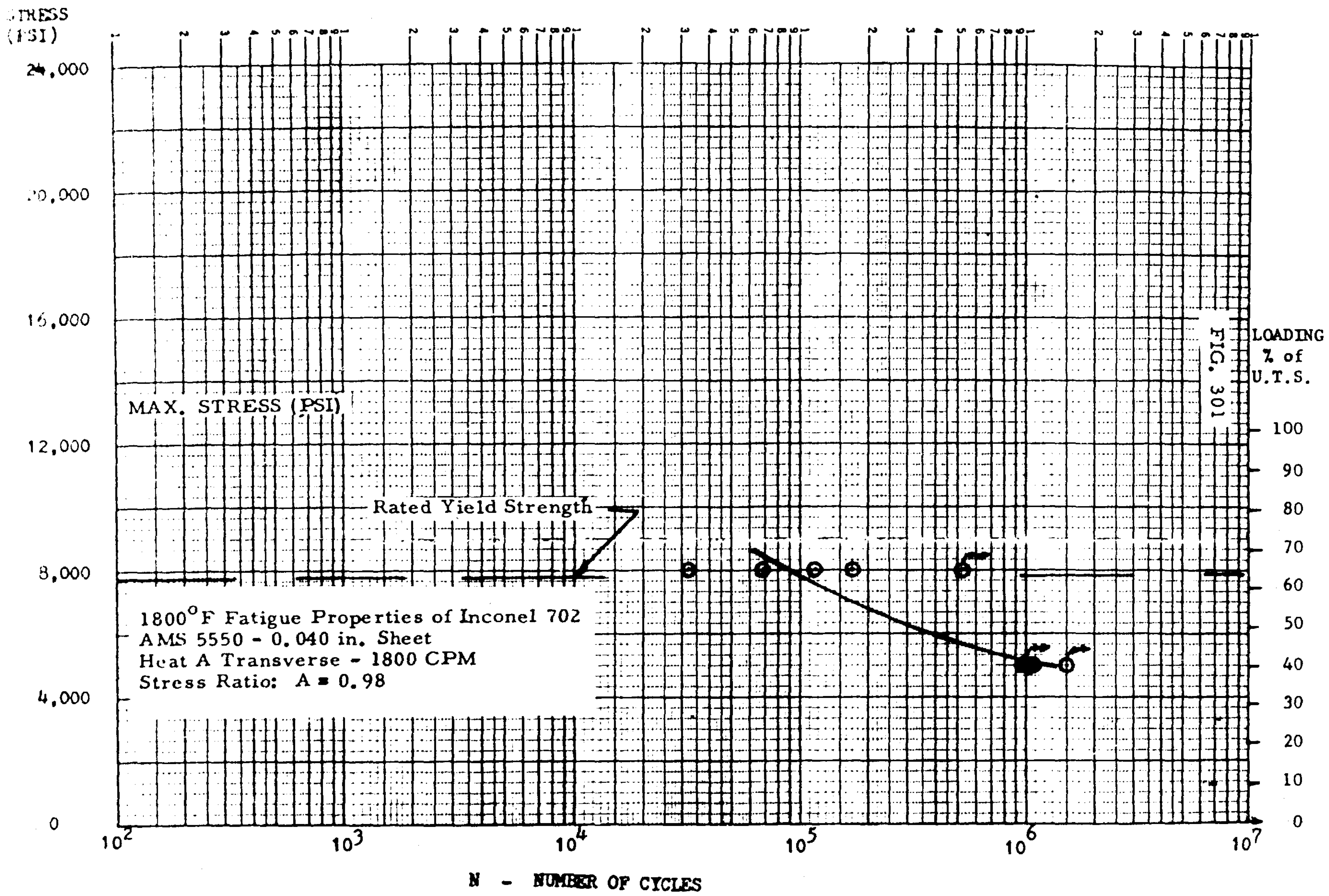


FIG. 301
STRESS (PSI)
24,000
20,000
16,000
12,000
8,000
4,000
0
MAX. STRESS (PSI)
Rated Yield Strength
1800°F Fatigue Properties of Inconel 702
AMS 5550 - 0.040 in. Sheet
Heat A Transverse - 1800 CPM
Stress Ratio: A = 0.98
LOADING
% of
U.T.S.
100
90
80
70
60
50
40
30
20
10
0
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 302

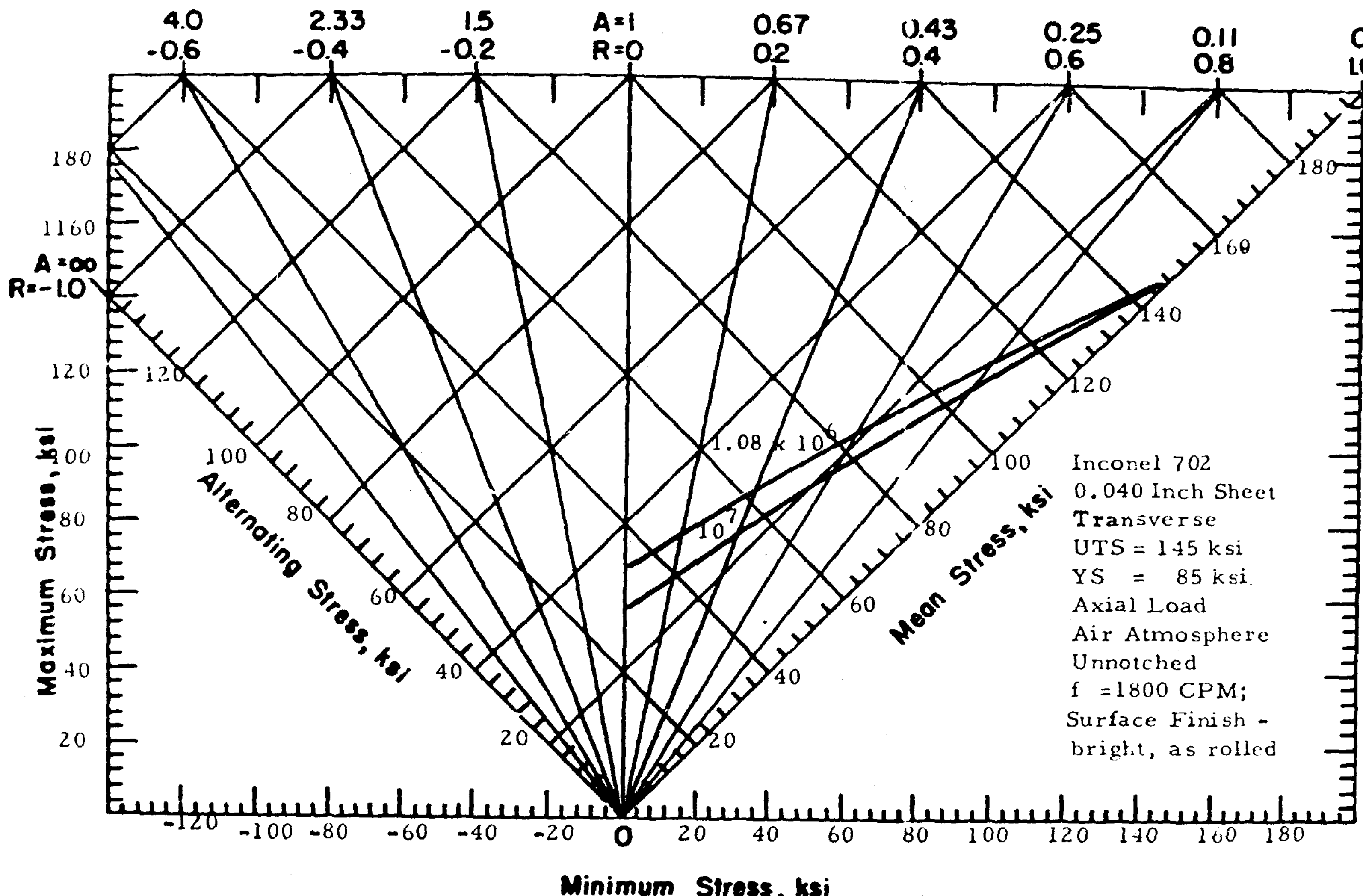


FIGURE
TYPICAL CONSTANT LIFE DIAGRAM FOR FATIGUE BEHAVIOR OF INCONEL 702 SHEET MATERIAL AT ROOM TEMPERATURE.

FIG. 303

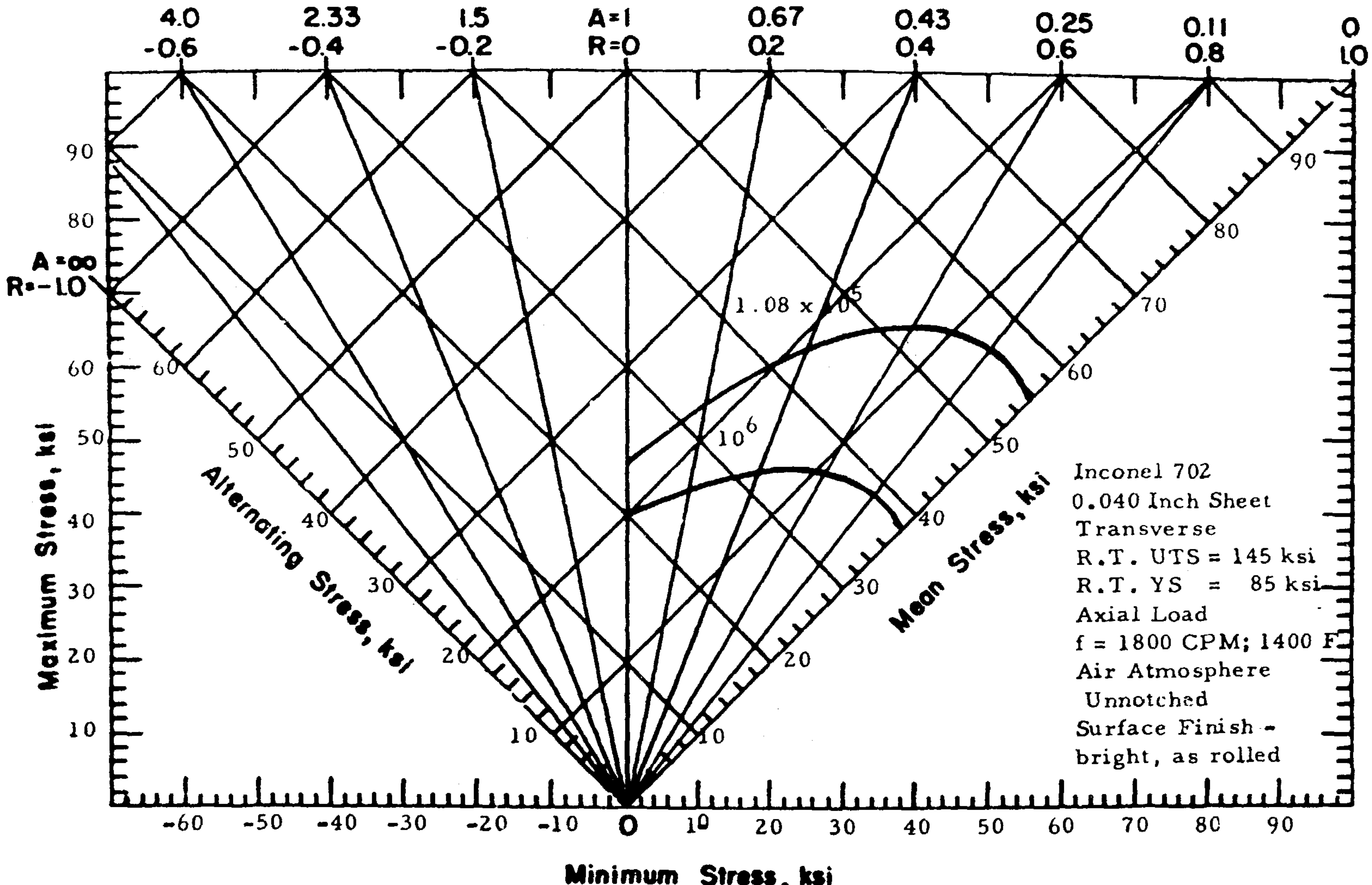


FIGURE
TYPICAL CONSTANT LIFE DIAGRAM OF FATIGUE BEHAVIOR OF INCOLOY 702 AT 1400 F

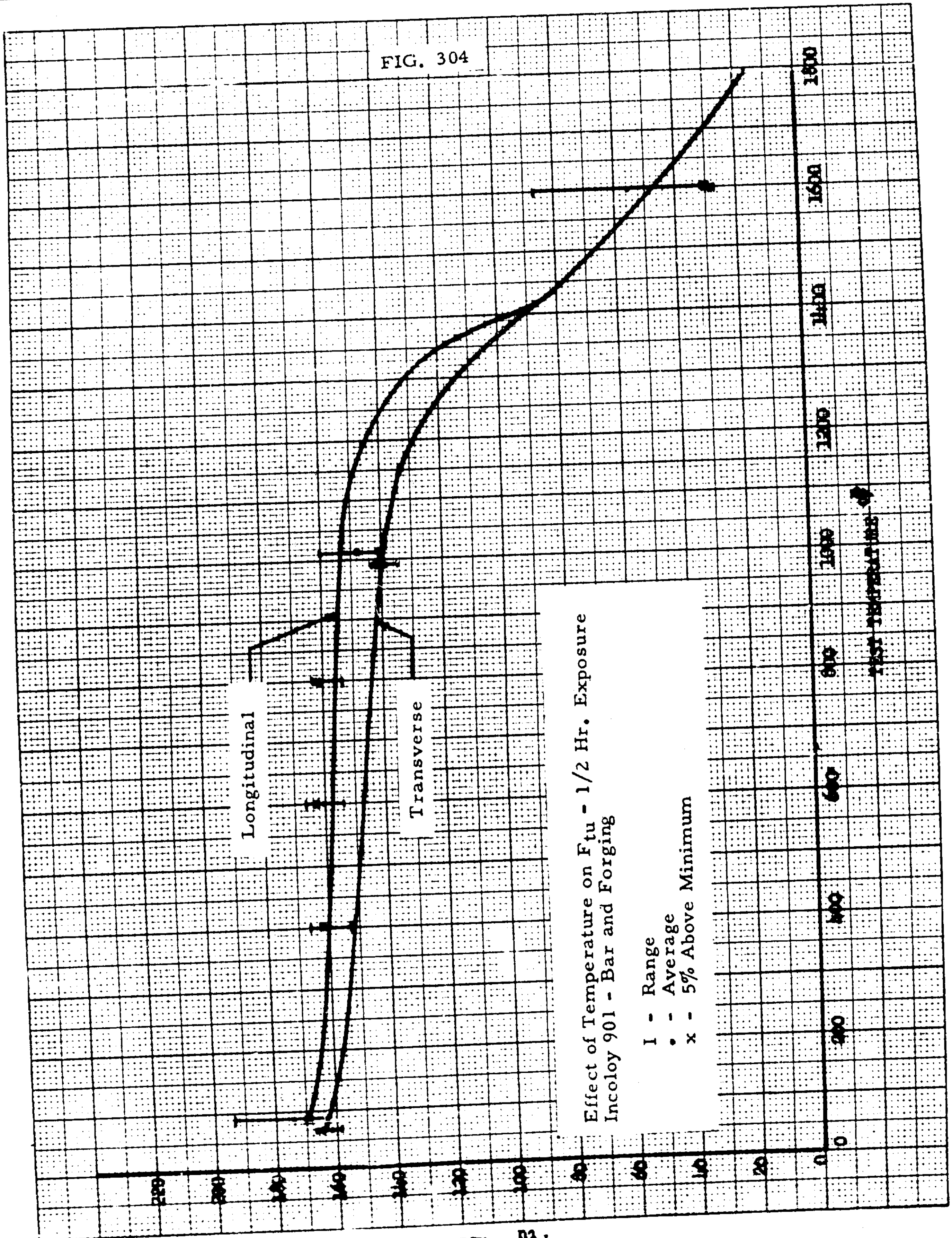
SECTION 7.4 MATERIAL, INCOLOY 901

TABLE OF CONTENTS

SECTION VII

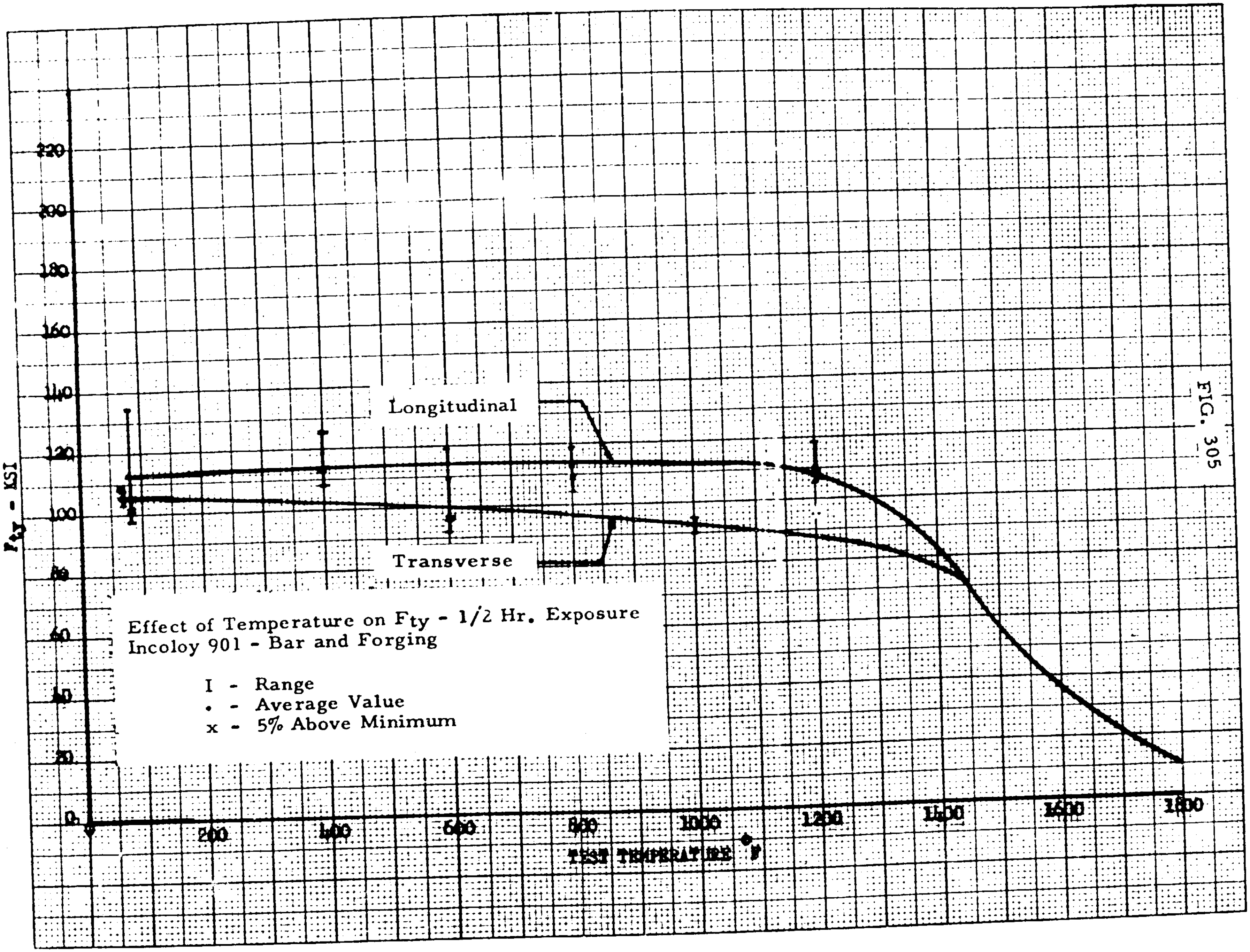
SECTION 7.4.1 TENSION

FIG. 304



Effect of Temperature on F_{tu} - 1/2 Hr. Exposure
Incoloy 901 - Bar and Forging
I - Range
• - Average
x - 5% Above Minimum
Longitudinal
Transverse
F_{tu} - KSI
TEST TEMPERATURE °F
0
200
400
600
800
1000
1200
1400
1600
1800
20
40
60
80
100
120
140
160
180
200
220

FIG. 305



Effect of Temperature on Fty - 1/2 Hr. Exposure
Incoloy 901 - Bar and Forging
I - Range
. - Average Value
x - 5% Above Minimum
Longitudinal
Transverse
Fty - KSI
TEST TEMPERATURE °F
0
20
40
60
80
100
120
140
160
180
200
220
200
400
600
800
1000
1200
1400
1600
1800

FIG. 306

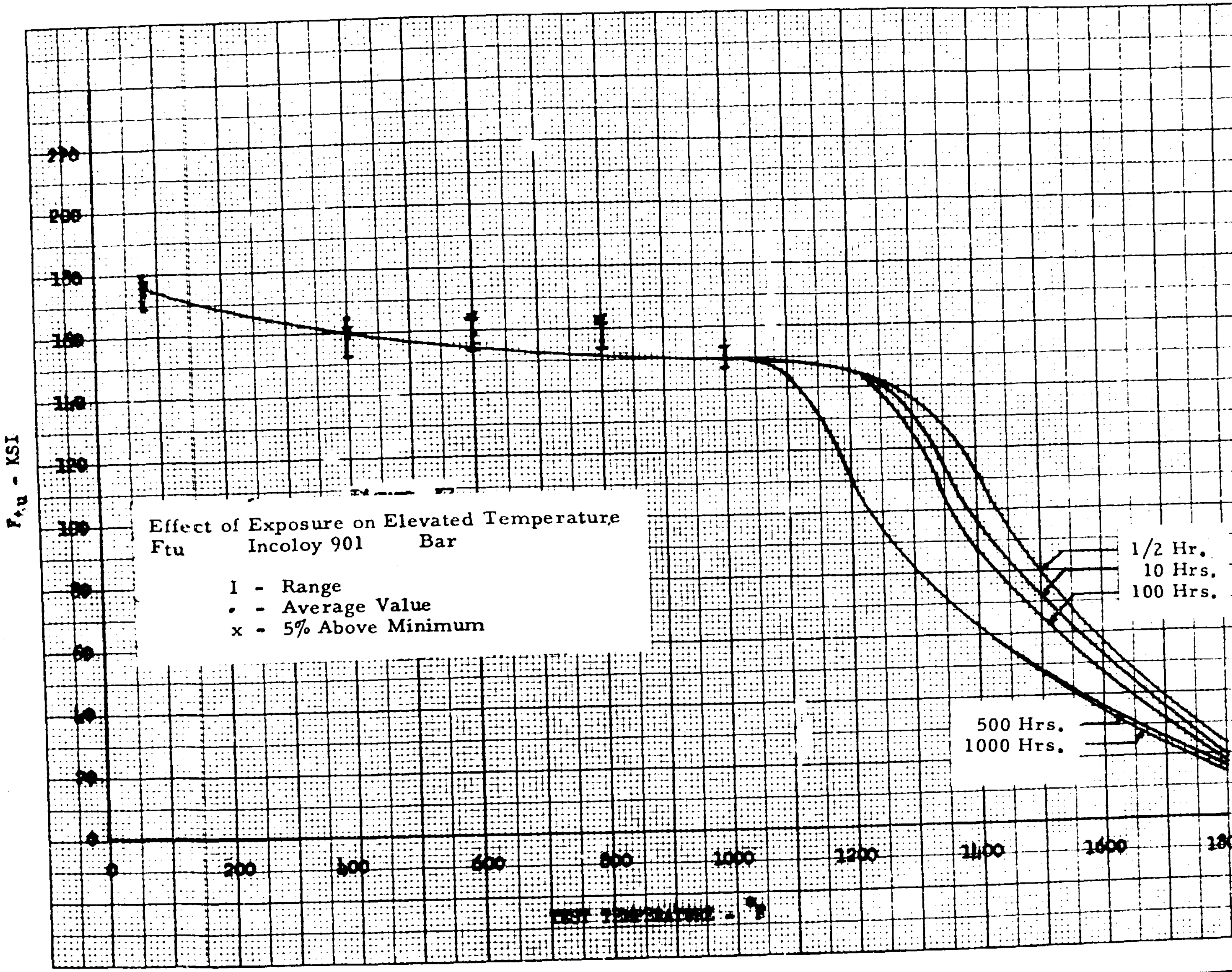

Effect of Exposure on Elevated Temperature
Ftu Incoloy 901 Bar
I - Range
. - Average Value
x - 5% Above Minimum
1/2 Hr.
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
F_{tu} - KSI
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 307

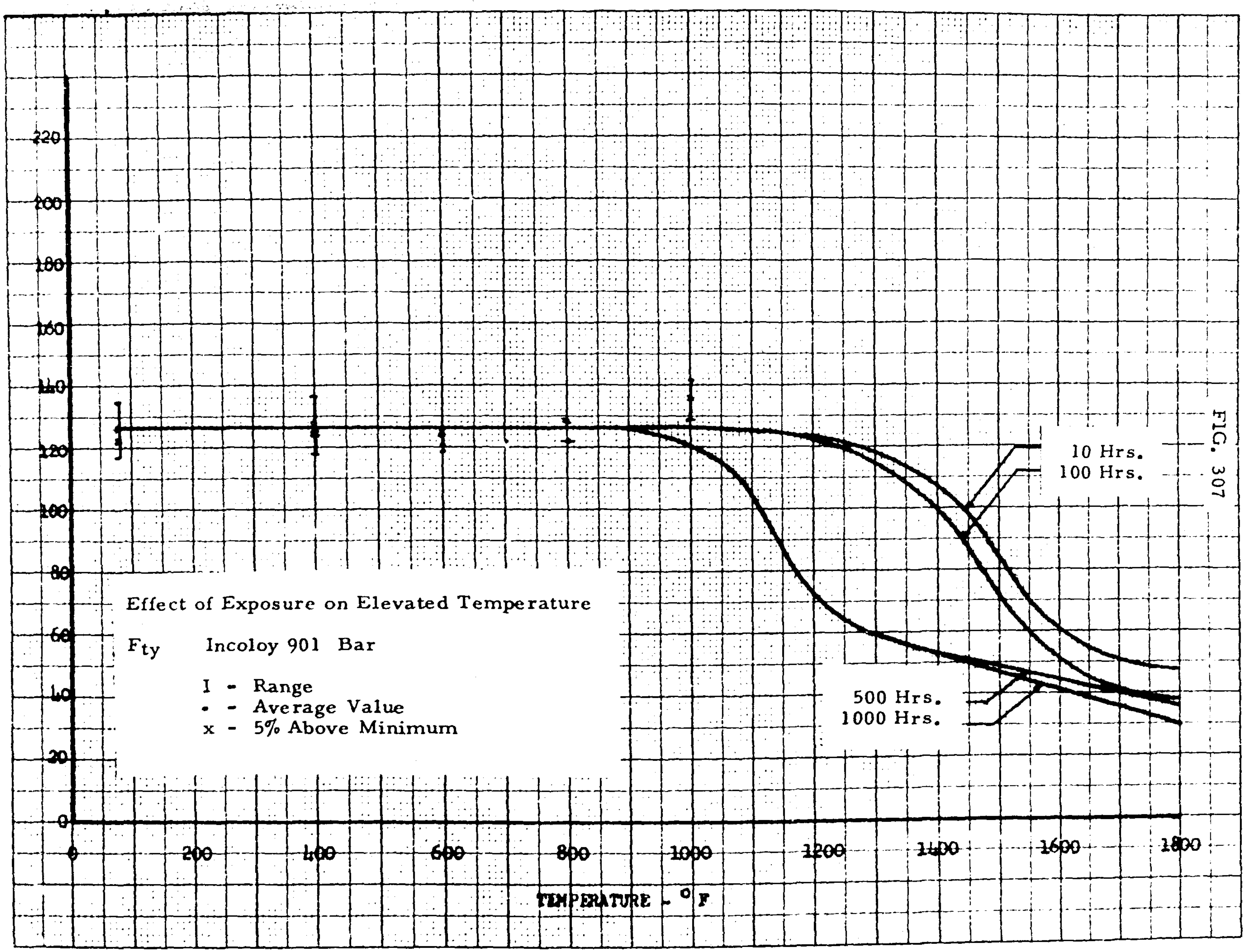
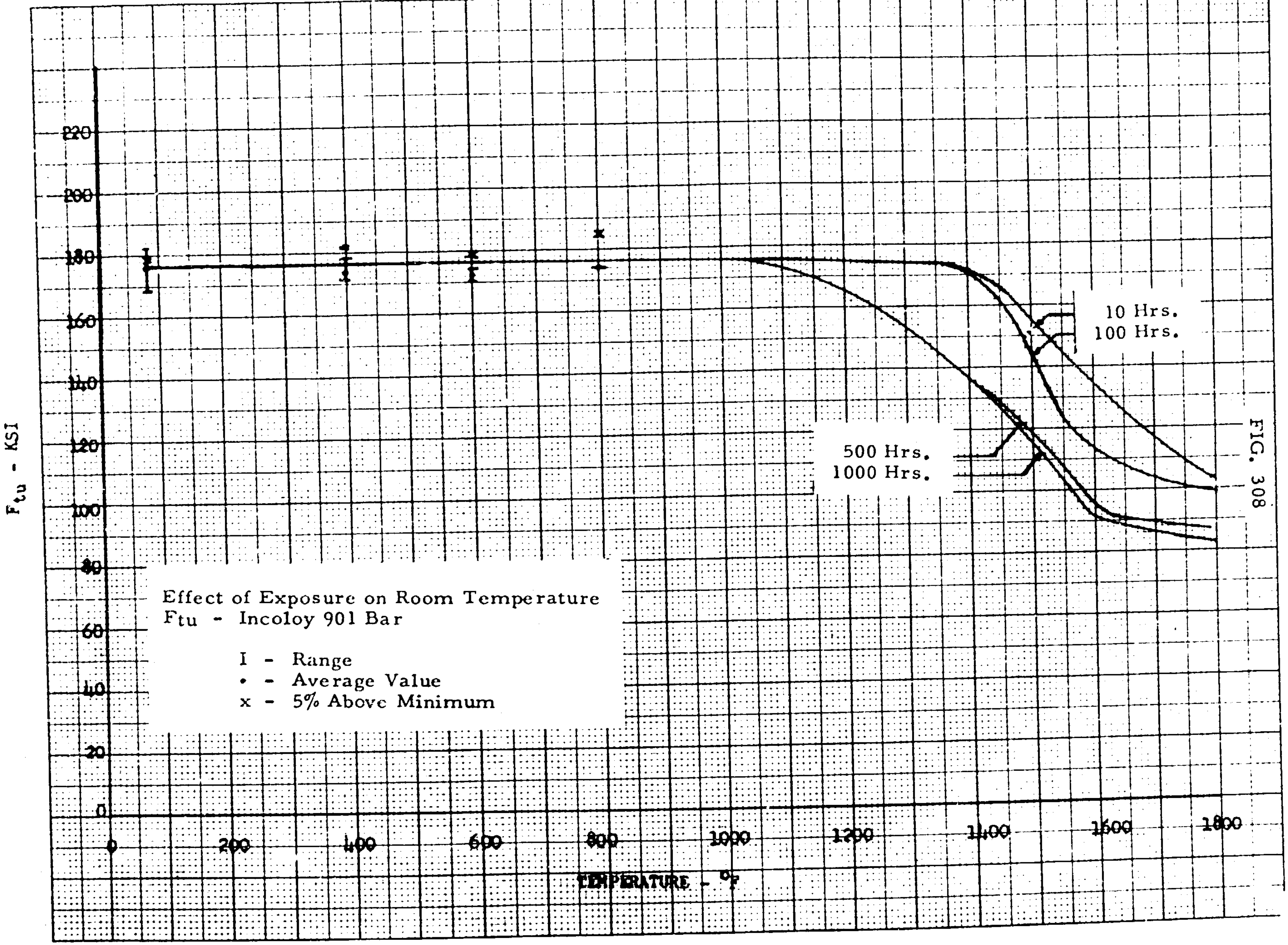

Effect of Exposure on Elevated Temperature
F_{ty} Incoloy 901 Bar
I - Range
• - Average Value
x - 5% Above Minimum
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
F_{ty} - KSI
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE - °F

FIG. 308



Effect of Exposure on Room Temperature
Ftu - Incoloy 901 Bar
I - Range
• - Average Value
x - 5% Above Minimum
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
220
200
180
160
140
120
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE - °F
F_{tu} - KSI

FIG. 309

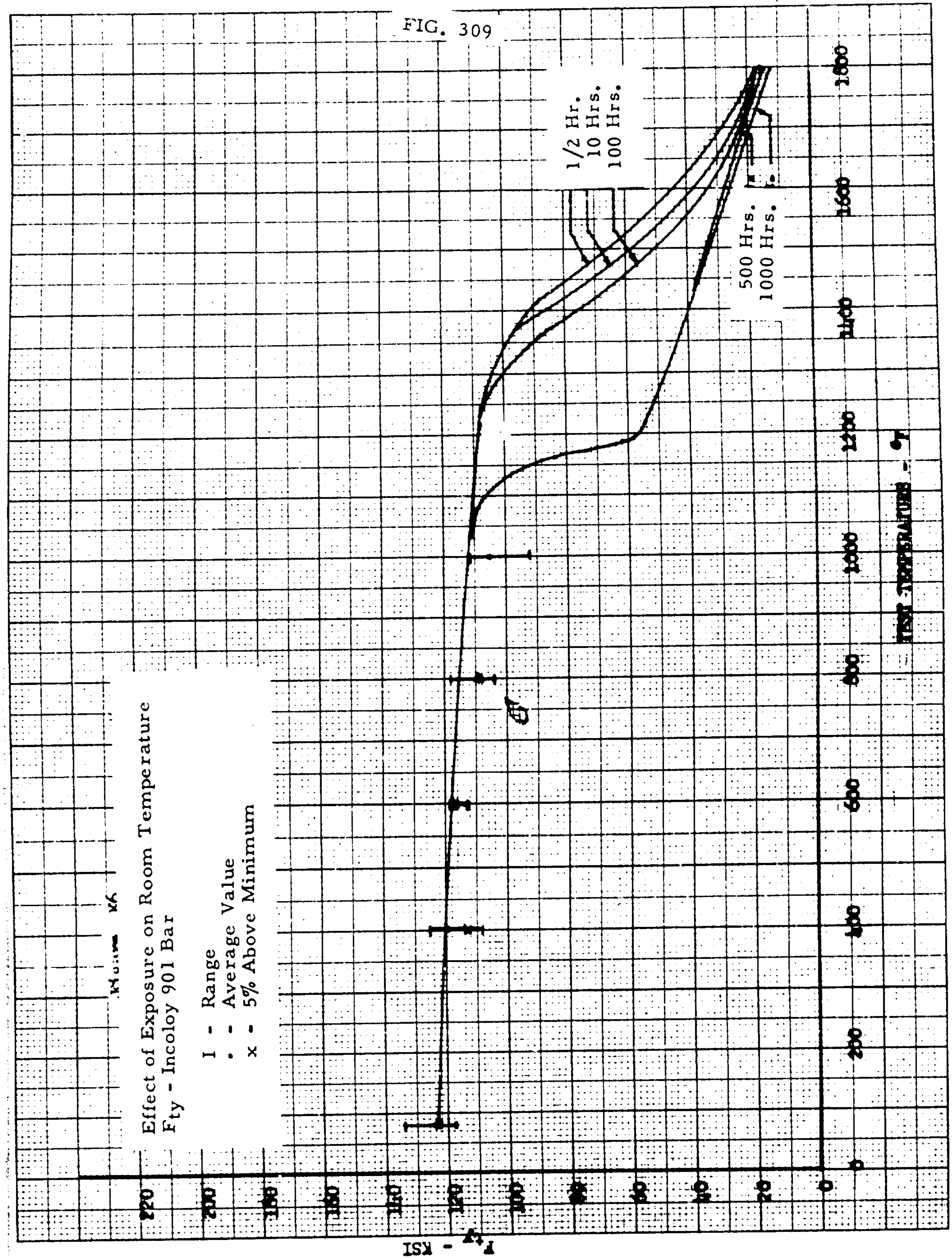
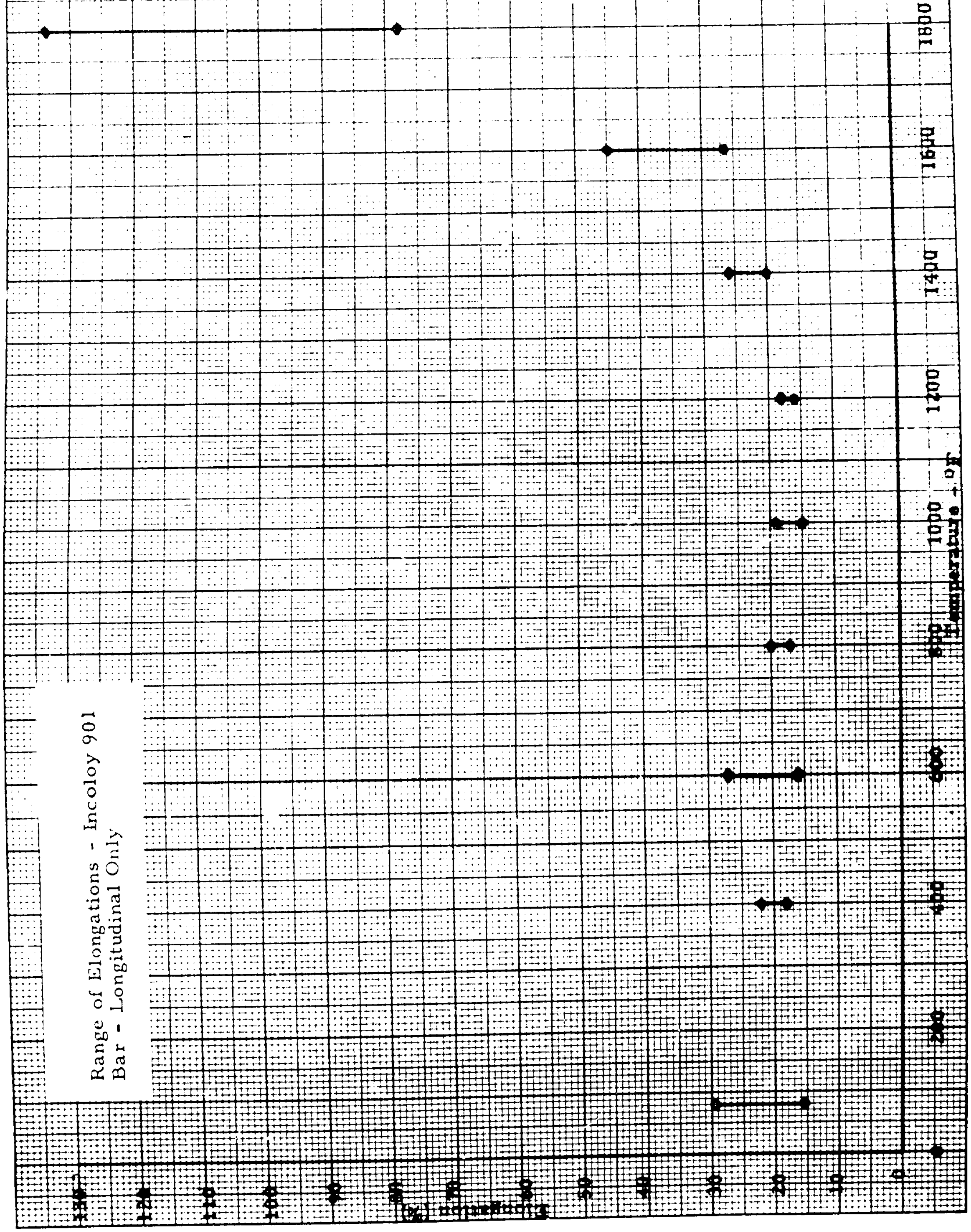
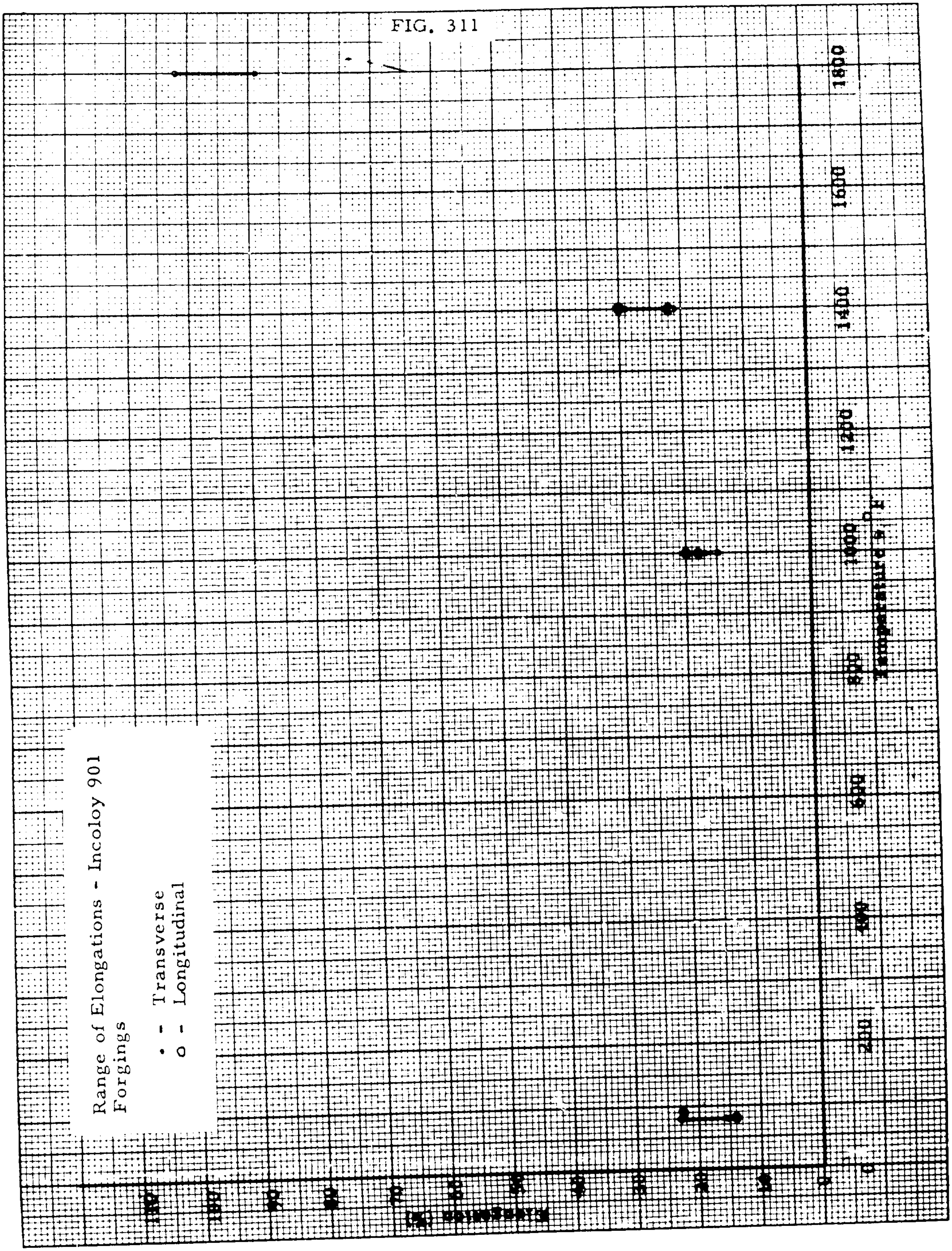

Effect of Exposure on Room Temperature
F_{ty} - Incoloy 901 Bar
I - Range
. - Average Value
x - 5% Above Minimum
1/2 Hr.
10 Hrs.
100 Hrs.
500 Hrs.
1000 Hrs.
F_{ty} - KSI
TEST TEMPERATURE - °F
0
20
40
60
80
100
120
140
160
180
200
220
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 310



Range of Elongations - Incoloy 901
Bar - Longitudinal Only
Temperature - °F
Elongation (%)
0
200
400
600
800
1000
1200
1400
1600
1800
10
20
30
40
50
60
70
80
90
100
110
120
130

FIG. 311

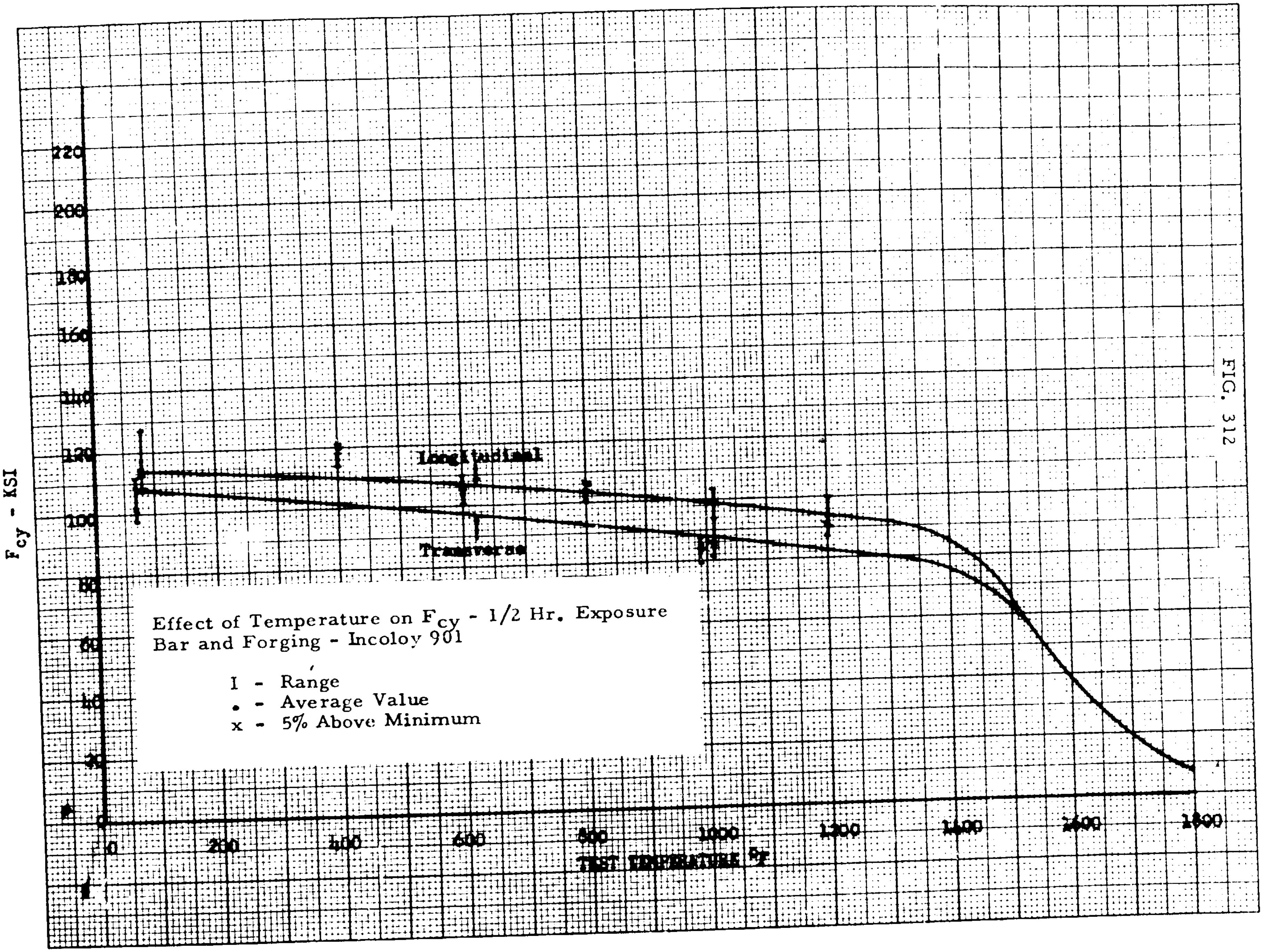


Range of Elongations - Incoloy 901
Forgings
• - Transverse
o - Longitudinal
0
200
400
600
800
1000
1200
1400
1600
1800
Temperature °F

SECTION VII

SECTION 7.4.2 COMPRESSION

FIG. 312



Effect of Temperature on F_{cy} - 1/2 Hr. Exposure
Bar and Forging - Incoloy 901

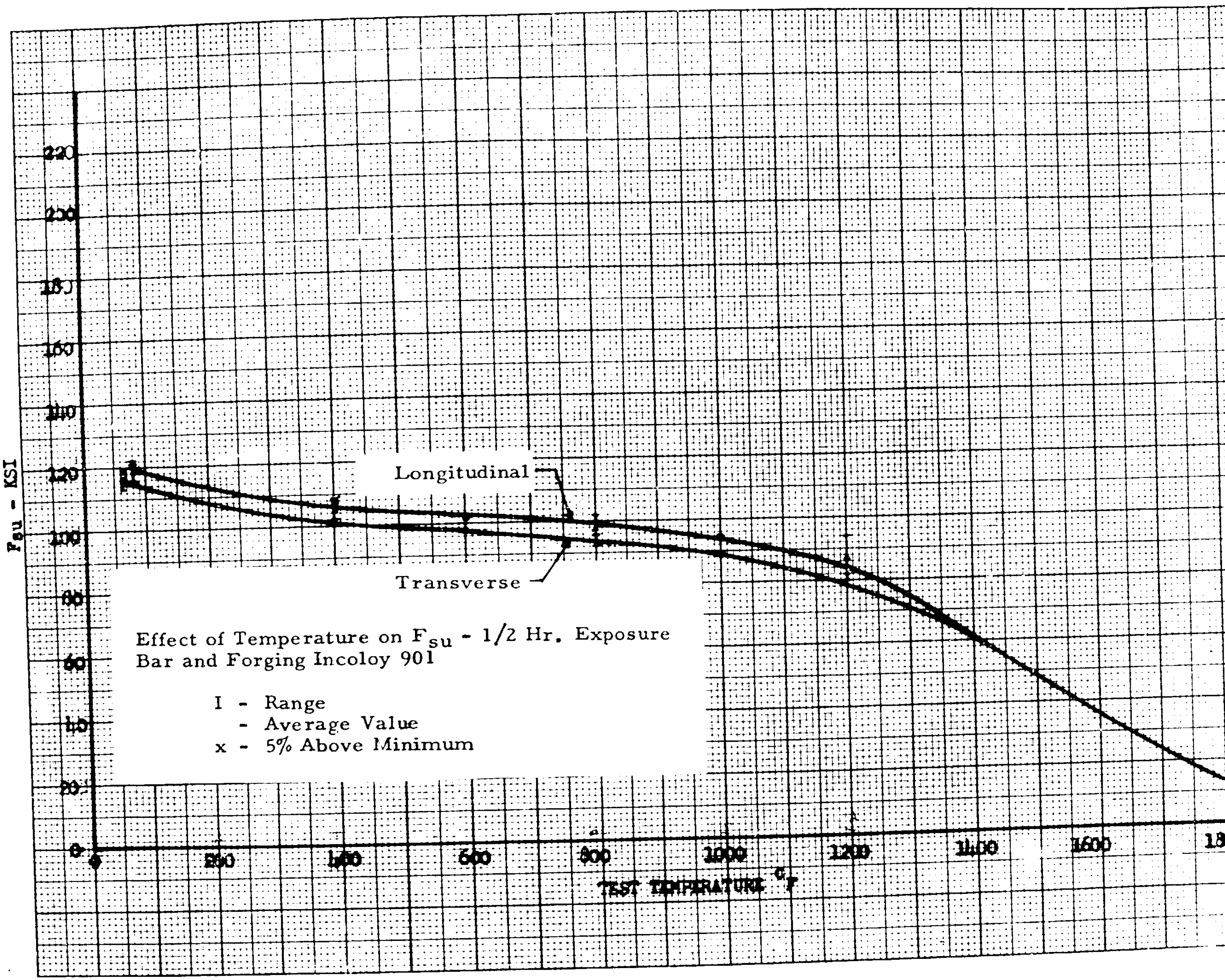
SECTION VII

SECTION 7.4.3 BEARING

SECTION VII

SECTION 7.4.4 SHEAR

FIG. 313


Effect of Temperature on F_{su} - 1/2 Hr. Exposure
Bar and Forging Incoloy 901
I - Range
- Average Value
x - 5% Above Minimum
Longitudinal
Transverse
F_{su} - KSI
220
200
180
160
140
120
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
TEST TEMPERATURE °F

SECTION VII

SECTION 7.4.5 CREEP

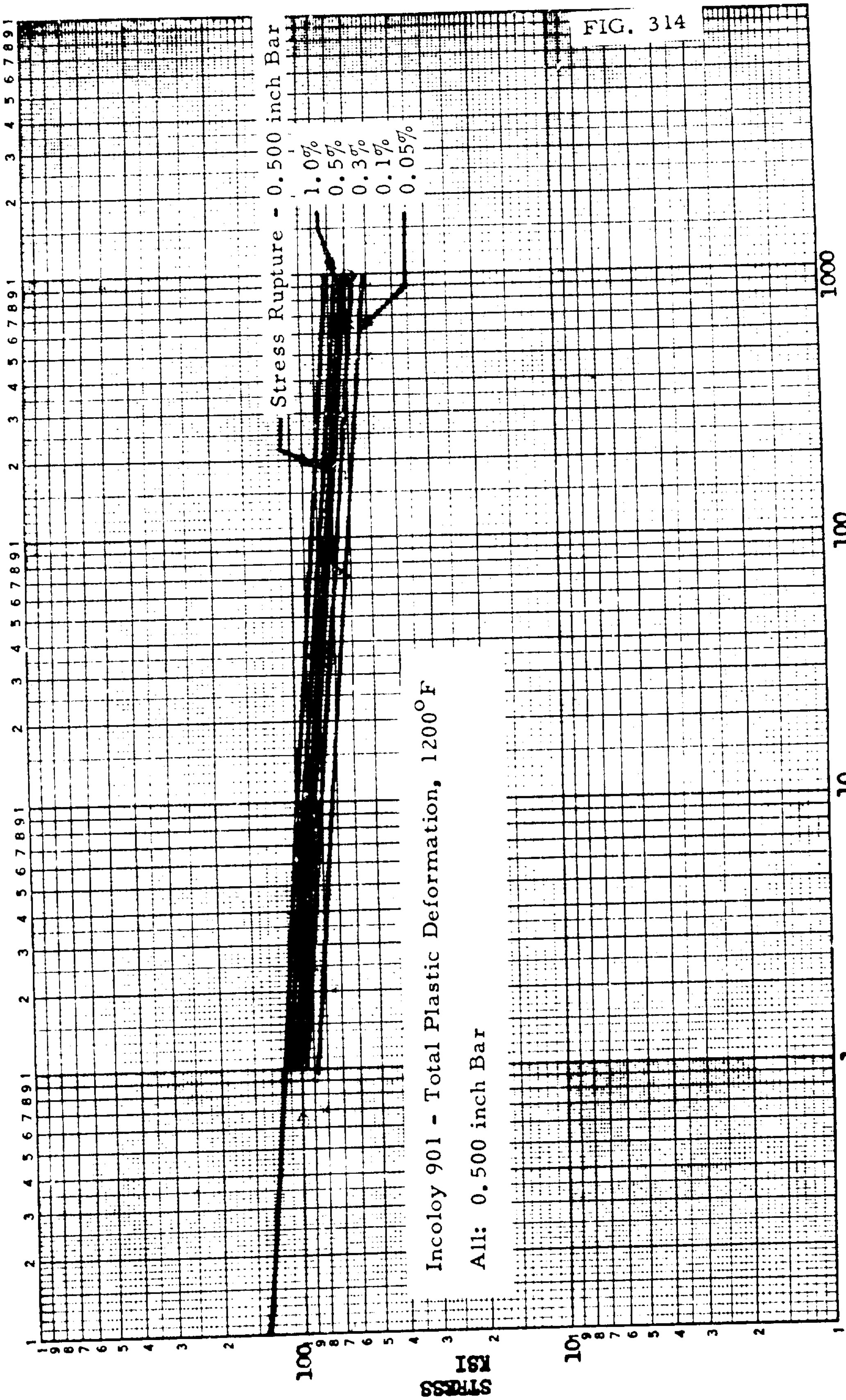

Stress Rupture - 0.500 inch Bar
1.0%
0.5%
0.3%
0.1%
0.05%
Incoloy 901 - Total Plastic Deformation, 1200°F
All: 0.500 inch Bar
1000
100
10
1
STRESS
KSI

FIG. 314

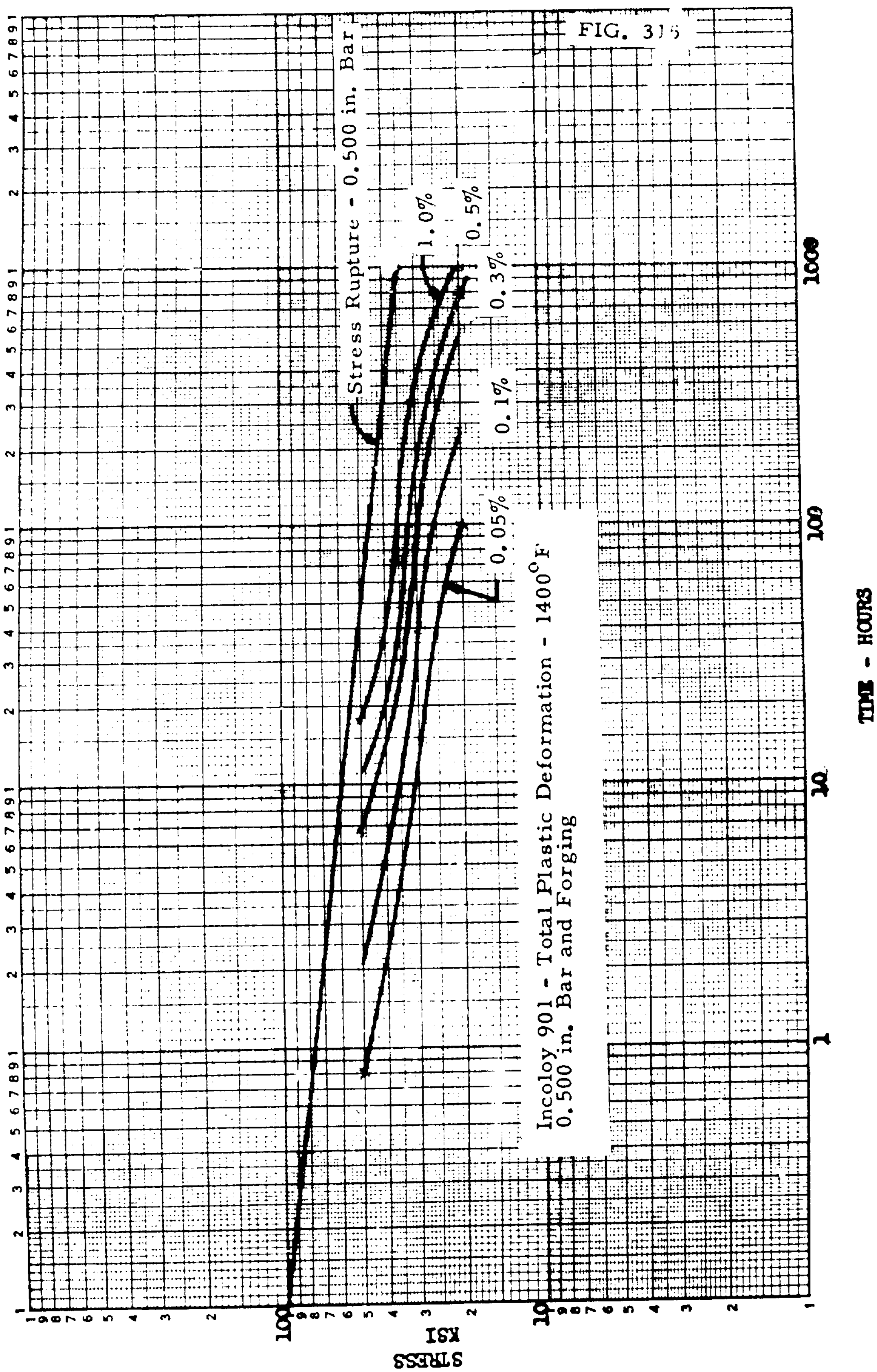


FIG. 315
Incoloy 901 - Total Plastic Deformation - 1400°F
0.500 in. Bar and Forging
Stress Rupture - 0.500 in. Bar
1.0%
0.5%
0.3%
0.1%
0.05%
TIME - HOURS
STRESS
KSI
1
10
100
1000

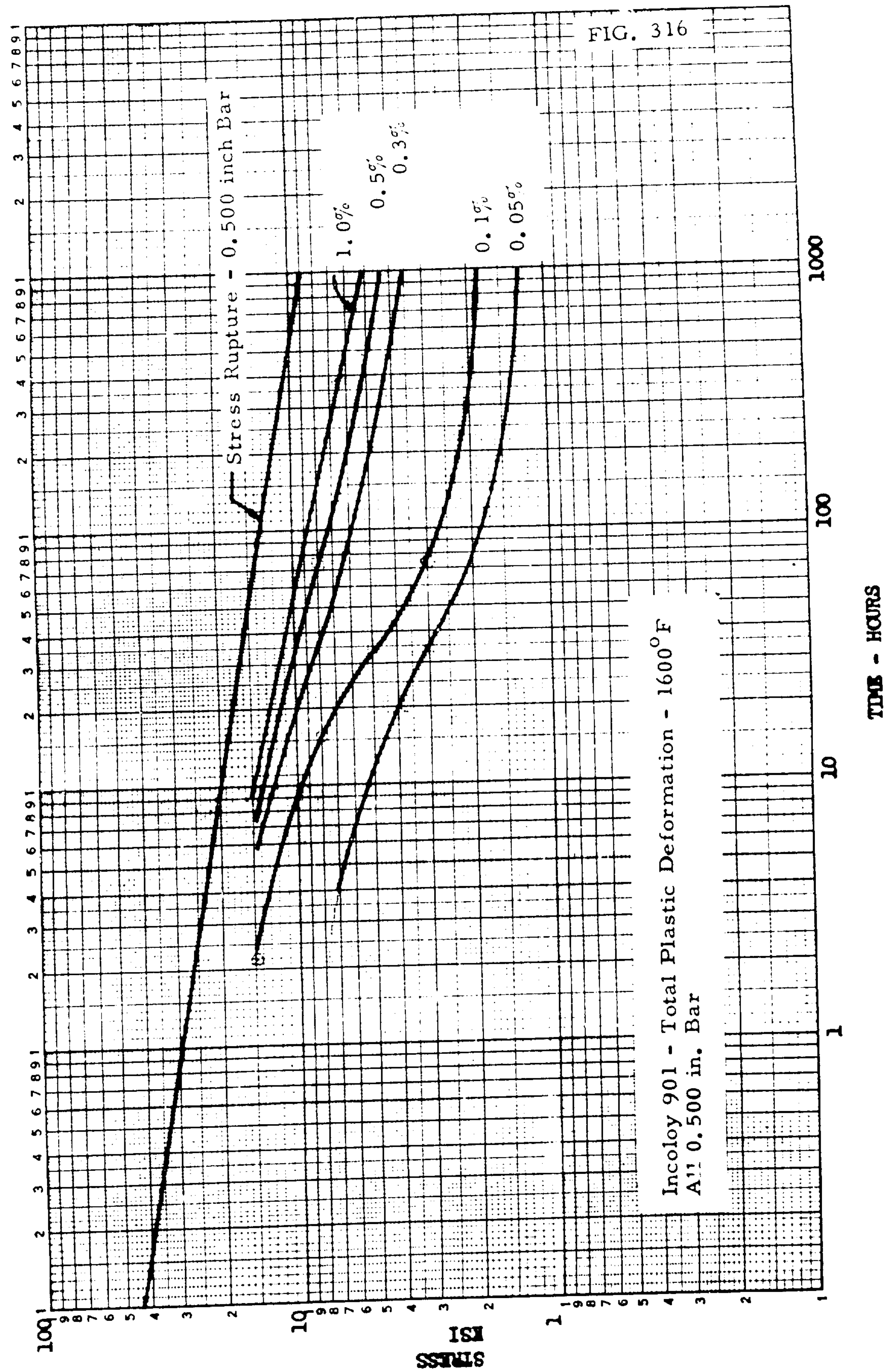


FIG. 316
Incoloy 901 - Total Plastic Deformation - 1600°F
A'' 0.500 in. Bar
Stress Rupture - 0.500 inch Bar
1.0%
0.5%
0.3%
0.1%
0.05%
STRESS
KSI
TIME - HOURS
100
10
1
1000

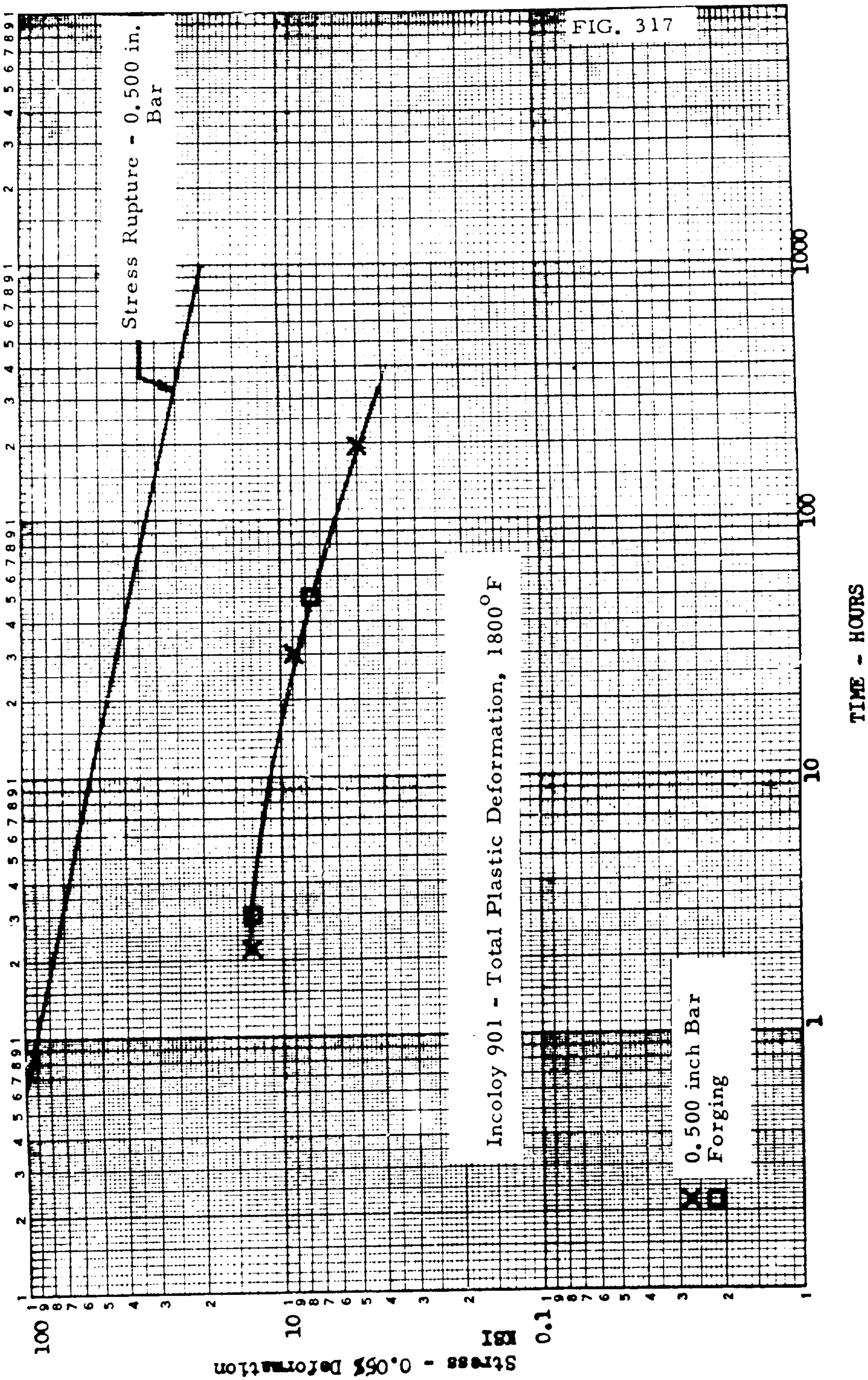
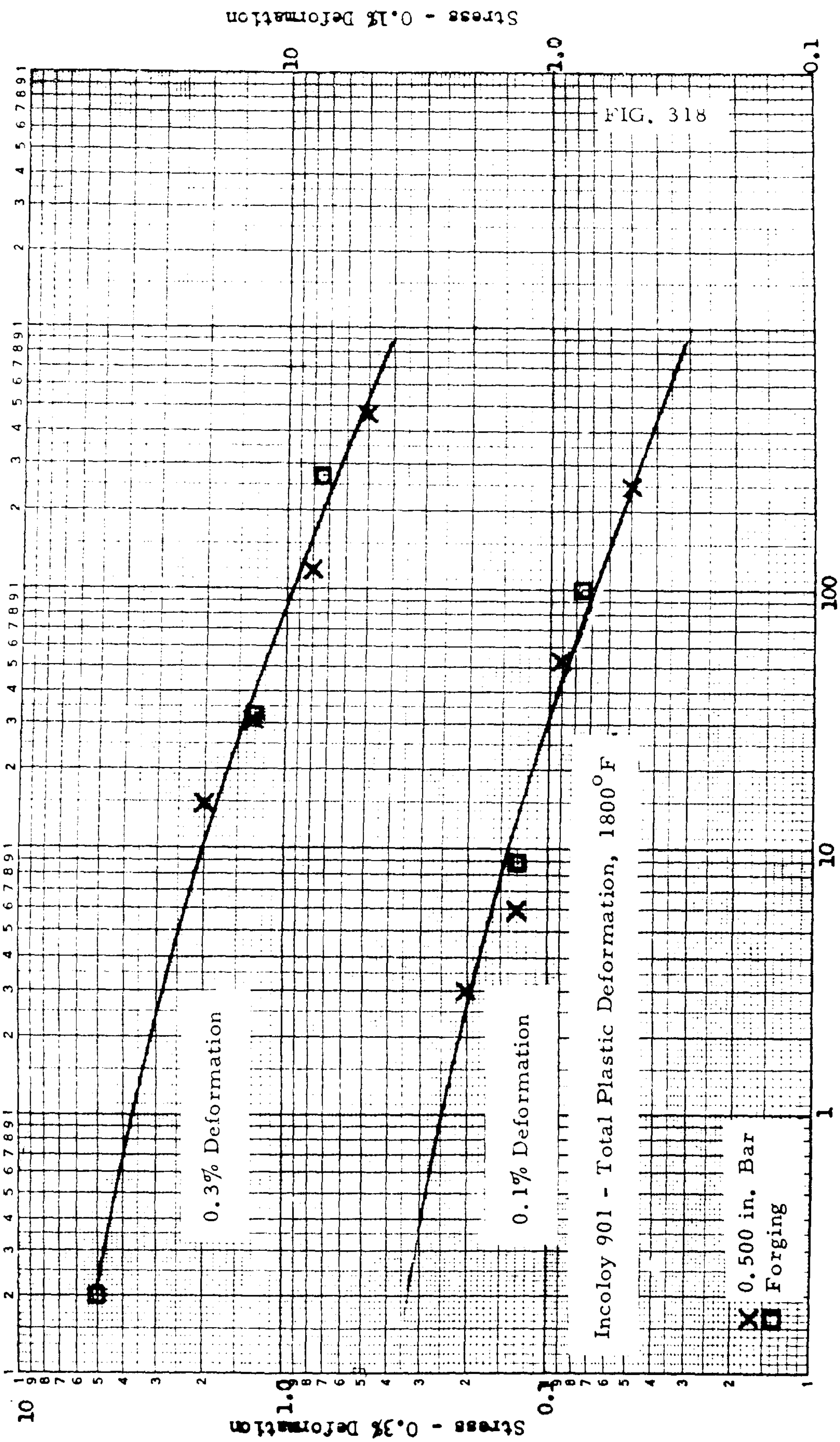


FIG. 317
Stress Rupture - 0.500 in. Bar
Incoloy 901 - Total Plastic Deformation, 1800°F
0.500 inch Bar Forging
TIME - HOURS
1
10
100
1000
KSI
0.1
10
100
Stress - 0.05% Deformation



Stress - 0.1% Deformation
Stress - 0.3% Deformation
Time - Hours
0.3% Deformation
0.1% Deformation
Incoloy 901 - Total Plastic Deformation, 1800°F
0.500 in. Bar
Forging

FIG. 318

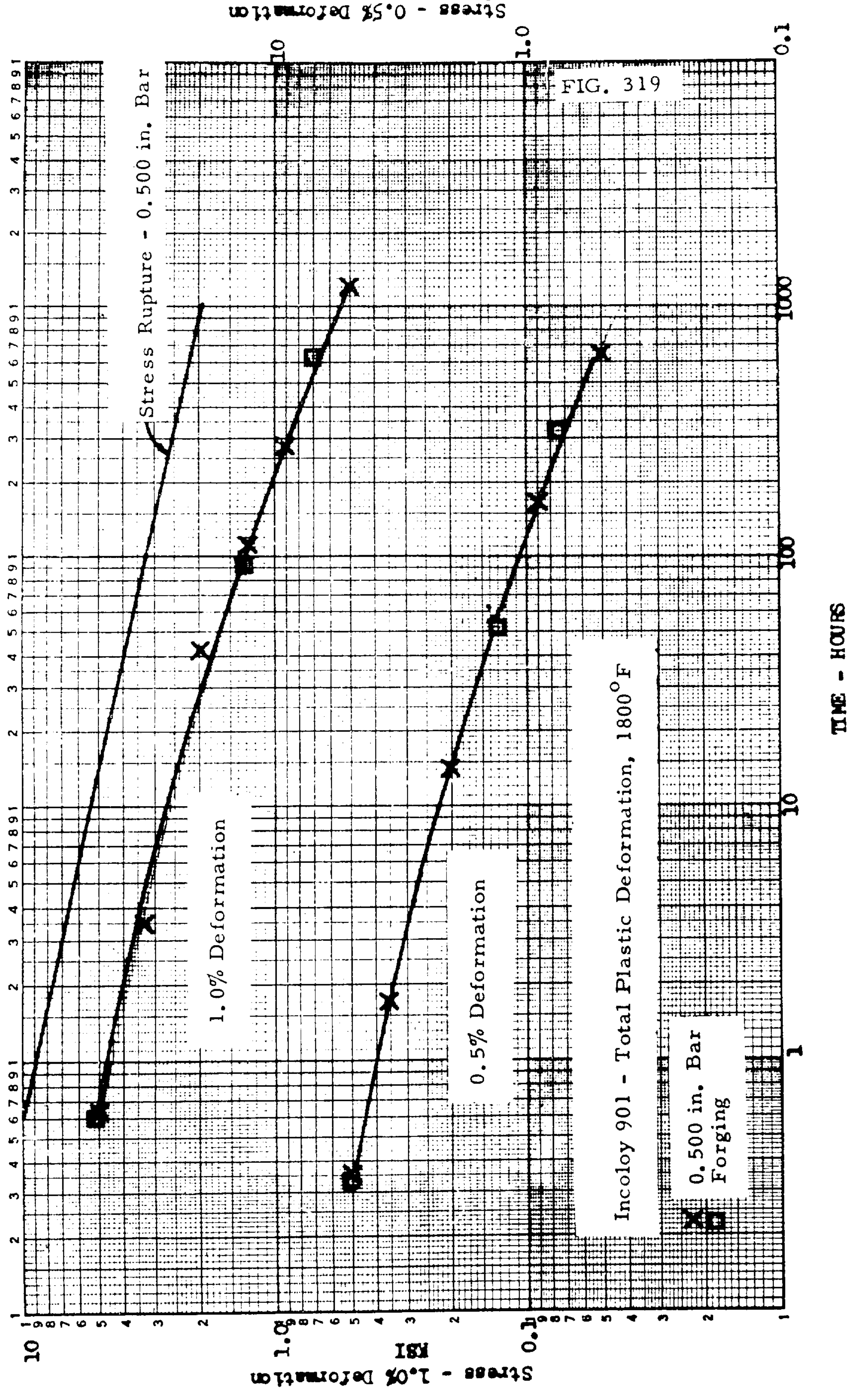
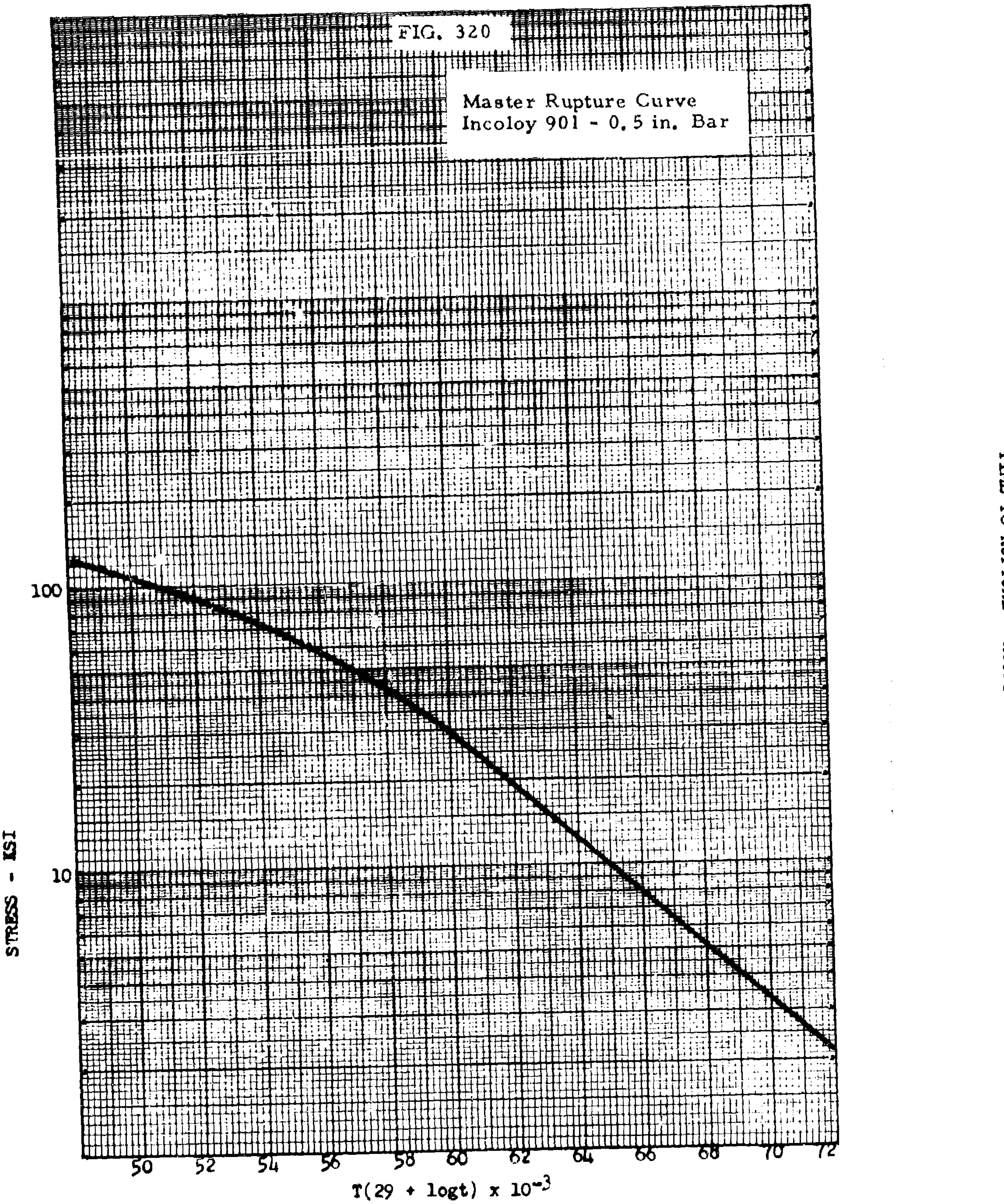


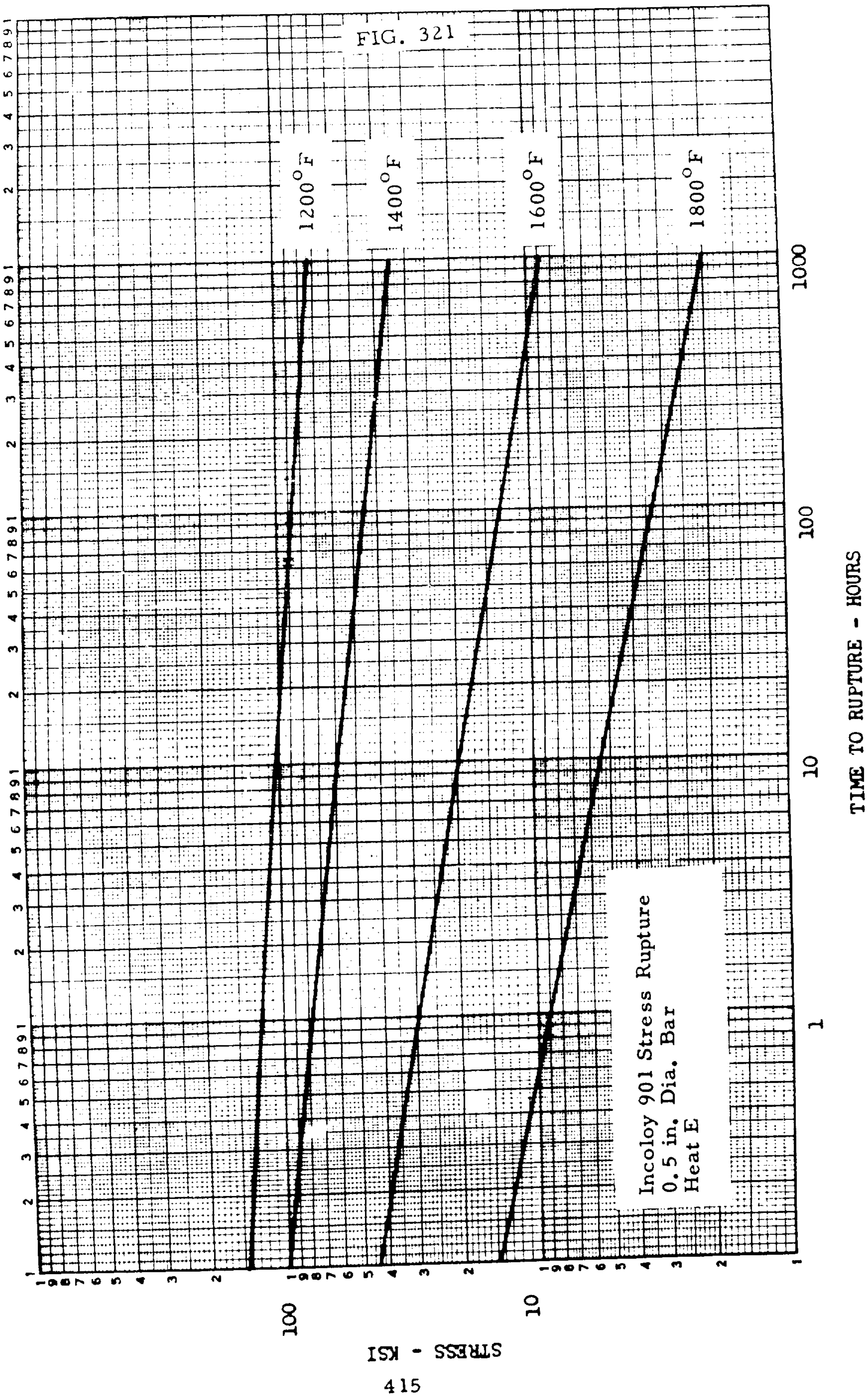
FIG. 319
Stress Rupture - 0.500 in. Bar
1.0% Deformation
0.5% Deformation
Incoloy 901 - Total Plastic Deformation, 1800°F
0.500 in. Bar Forging
TIME - HOURS
Stress - 1.0% Deformation KSI
Stress - 0.5% Deformation KSI
10
1.0
0.1
1
10
100
1000

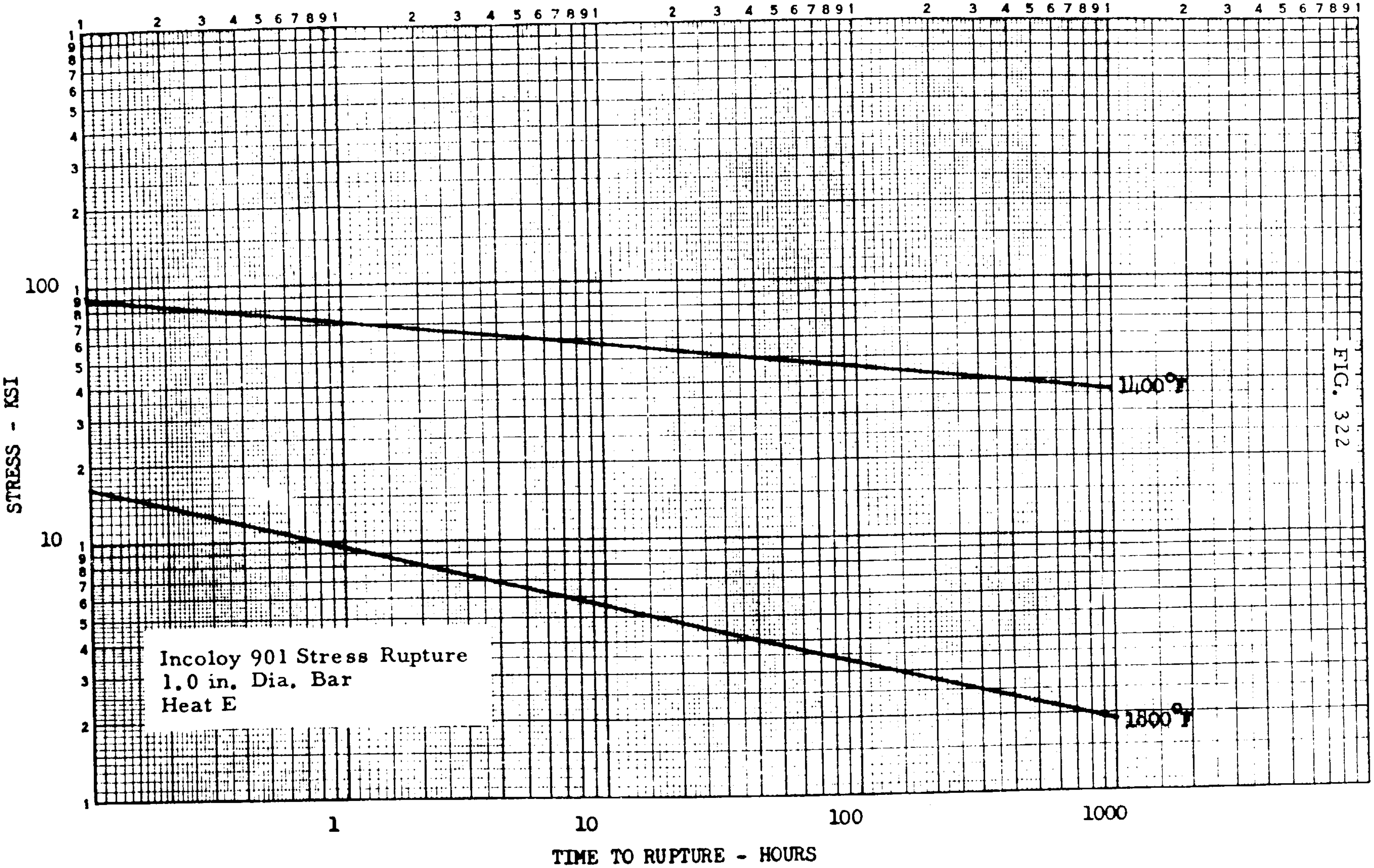
SECTION VII

SECTION 7.4.6 STRESS RUPTURE

FIG. 320


Master Rupture Curve
Incoloy 901 - 0.5 in. Bar
100
10
STRESS - KSI
50
52
54
56
58
60
62
64
66
68
70
72
T(29 + logt) x 10^{-3}
TIME TO RUPTURE - HOURS


1200°F
1400°F
1600°F
1800°F
Incoloy 901 Stress Rupture
0.5 in. Dia. Bar
Heat E
TIME TO RUPTURE - HOURS
1
10
100
1000
STRESS - KSI
10
100
FIG. 321


Incoloy 901 Stress Rupture
1.0 in. Dia. Bar
Heat E
1100°F
1800°F
STRESS - KSI
100
10
TIME TO RUPTURE - HOURS
1
10
100
1000
FIG. 322

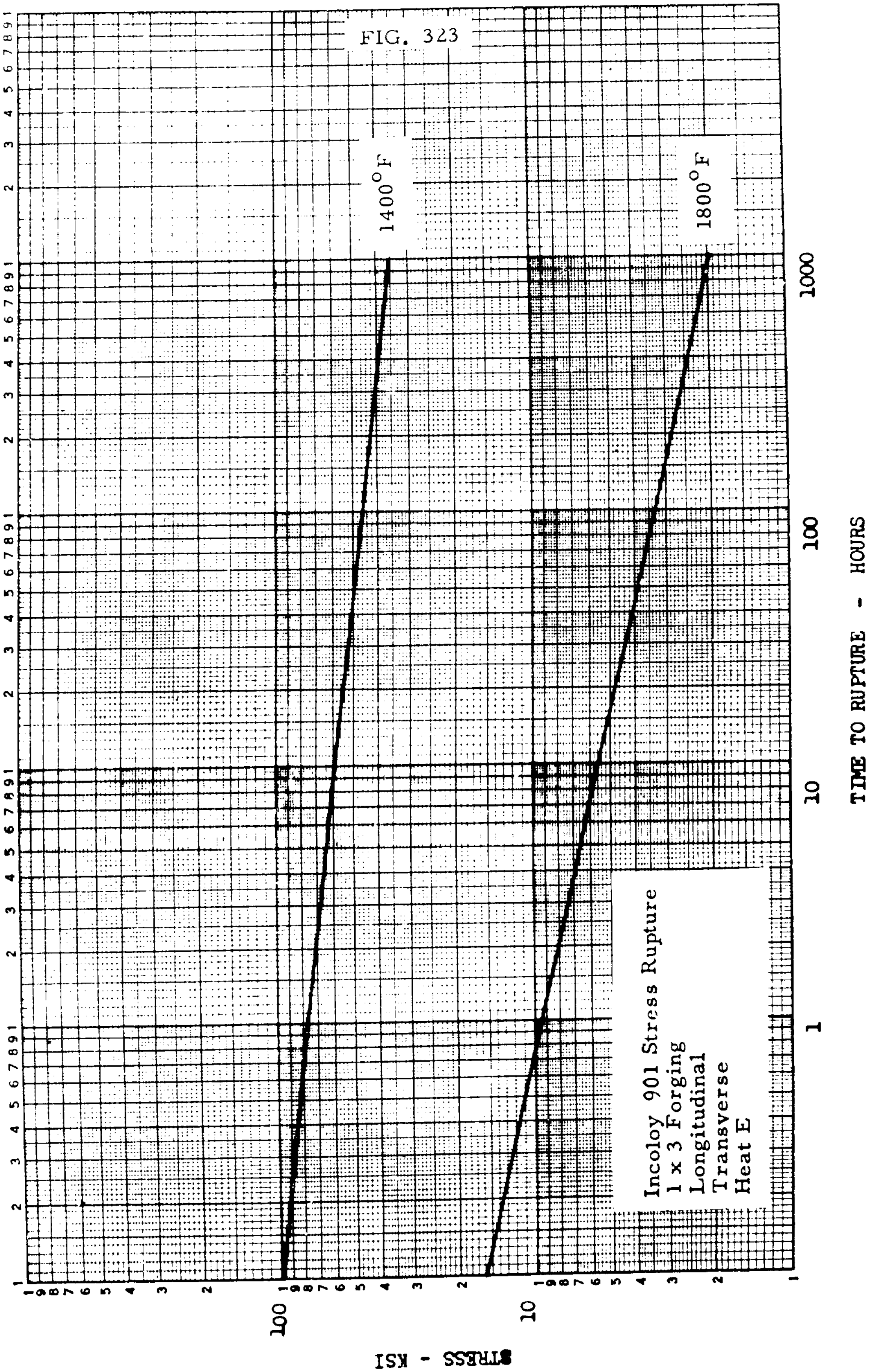


FIG. 323
1400°F
1800°F
Incoloy 901 Stress Rupture
1 x 3 Forging
Longitudinal
Transverse
Heat E
TIME TO RUPTURE - HOURS
1
10
100
1000
STRESS - KSI
10
100

SECTION VII

SECTION 7.4.7 FATIGUE

N - NUMBER OF CYCLES

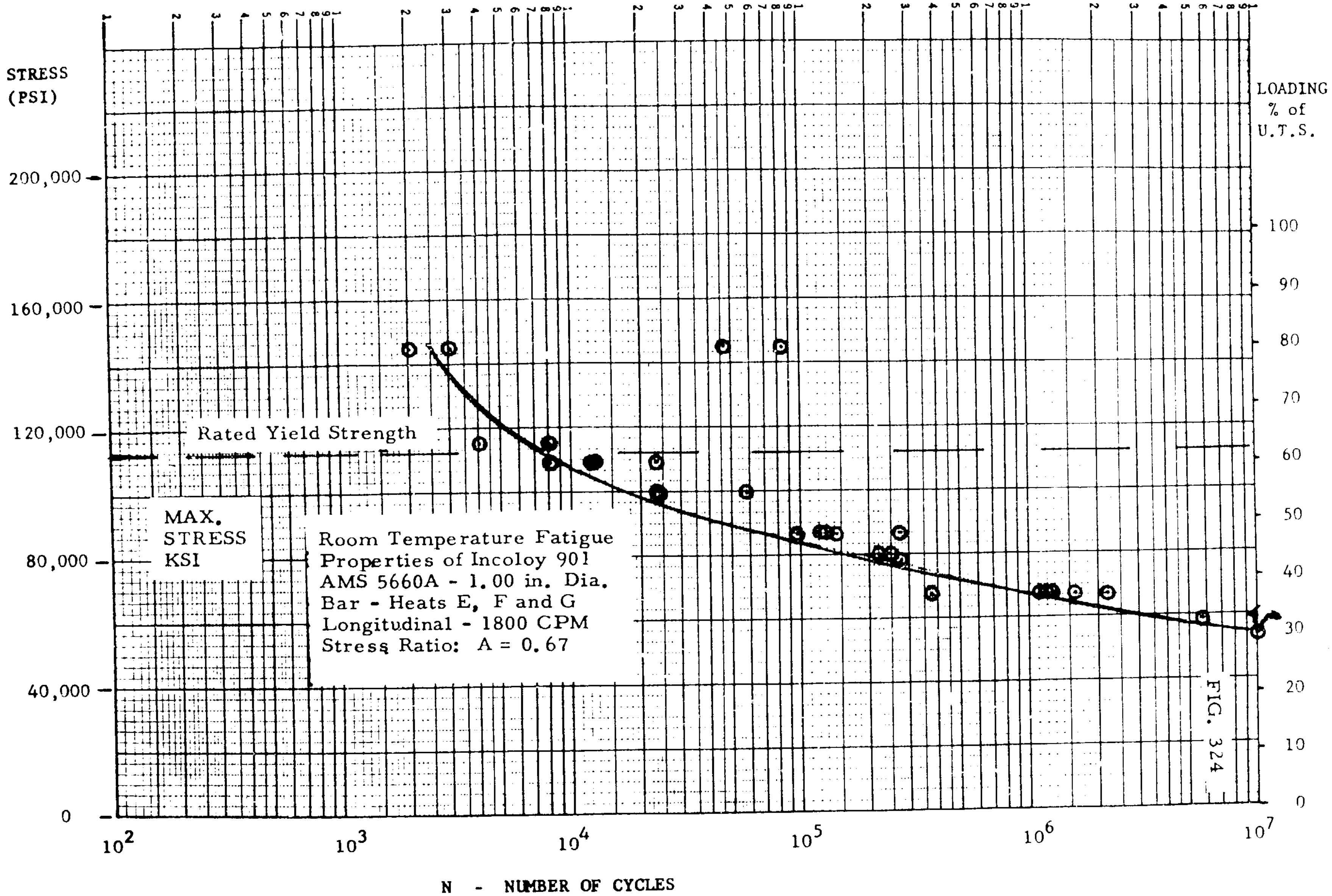

STRESS (PSI)
200,000
160,000
120,000
80,000
40,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS KSI
Room Temperature Fatigue
Properties of Incoloy 901
AMS 5660A - 1.00 in. Dia.
Bar - Heats E, F and G
Longitudinal - 1800 CPM
Stress Ratio: A = 0.67
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 324

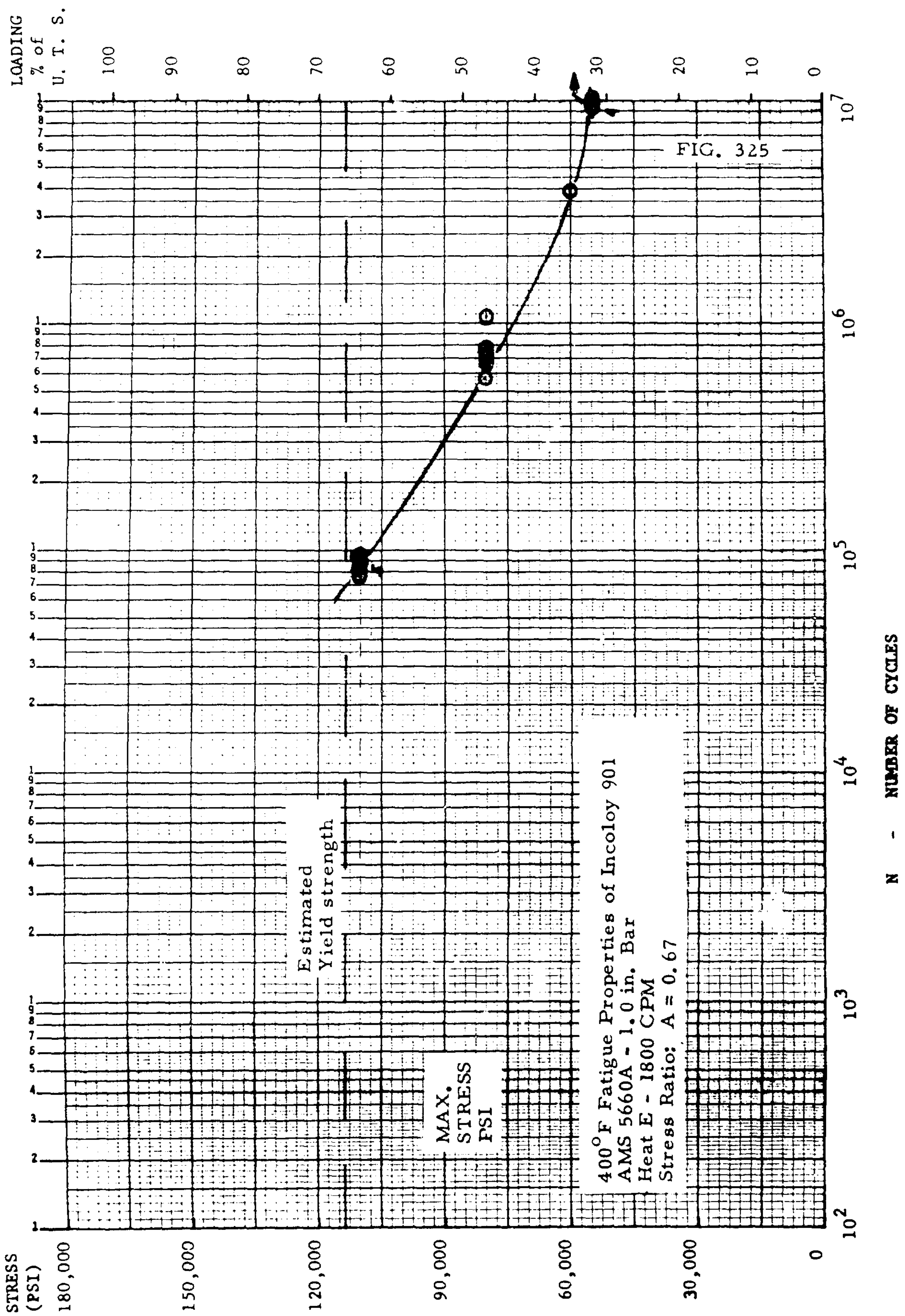


FIG. 325
400°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.67
Estimated Yield strength
MAX. STRESS PSI
LOADING % of U. T. S.
100
90
80
70
60
50
40
30
20
10
0
STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

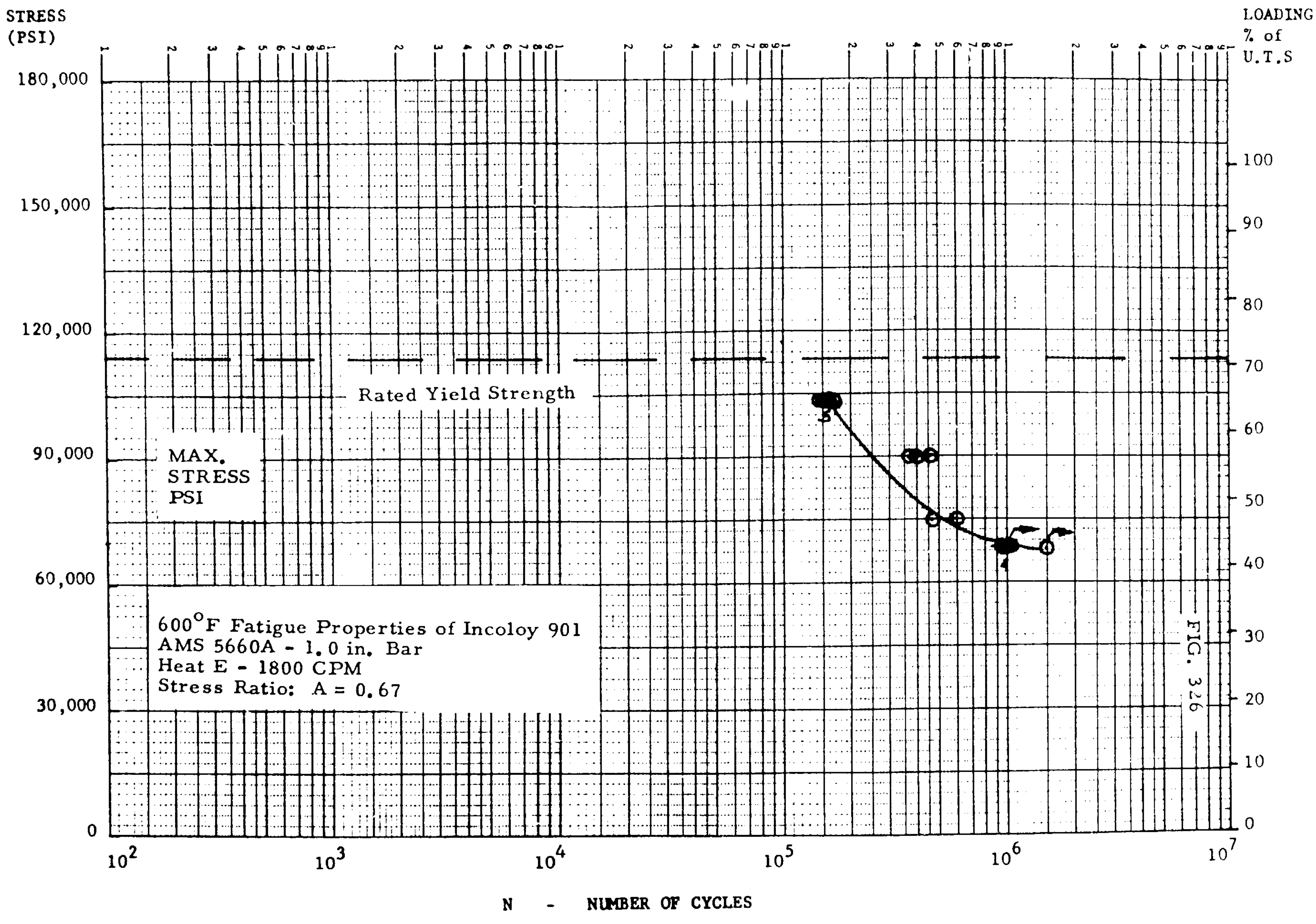
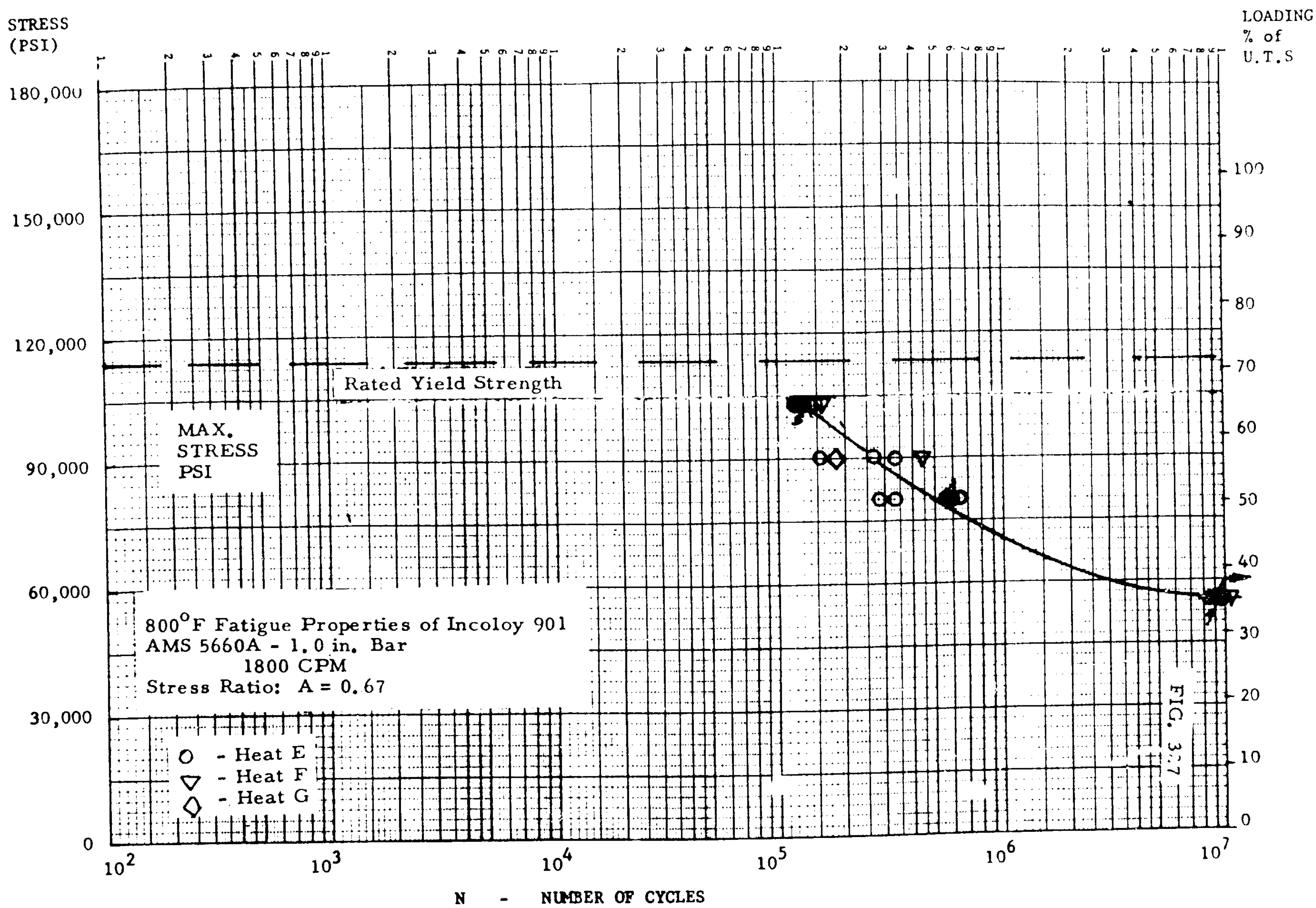

STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U.T.S
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
600°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.67
10²
10³
10⁴
10⁵
10⁶
10⁷
N - NUMBER OF CYCLES

FIG. 326


STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U.T.S
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS PSI
800°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
1800 CPM
Stress Ratio: A = 0.67
○ - Heat E
▽ - Heat F
◇ - Heat G
FIG. 3?7
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

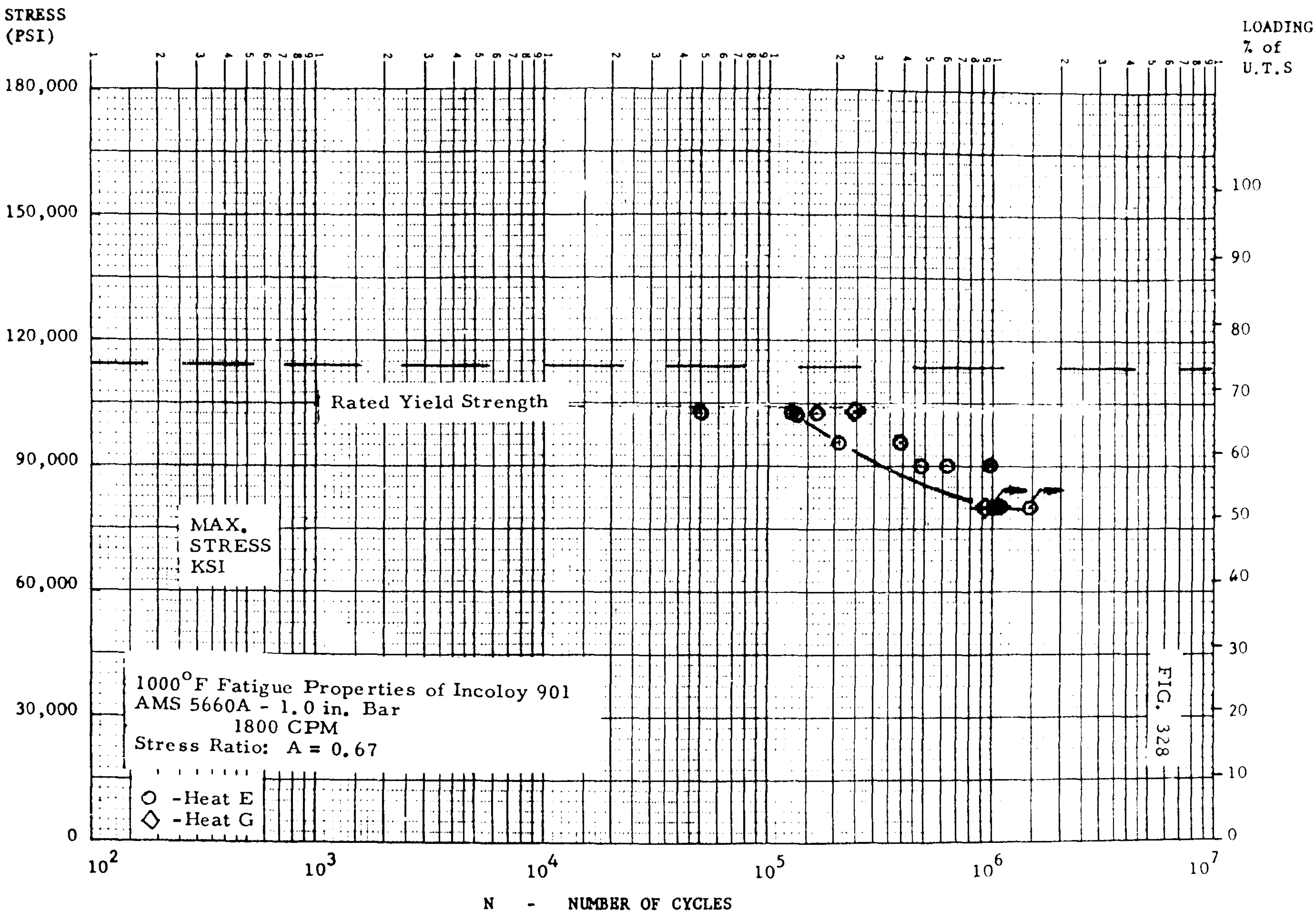

STRESS (PSI)
180,000
150,000
120,000
90,000
60,000
30,000
0
LOADING % of U.T.S
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS KSI
1000°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
1800 CPM
Stress Ratio: A = 0.67
○ -Heat E
◇ -Heat G
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 328

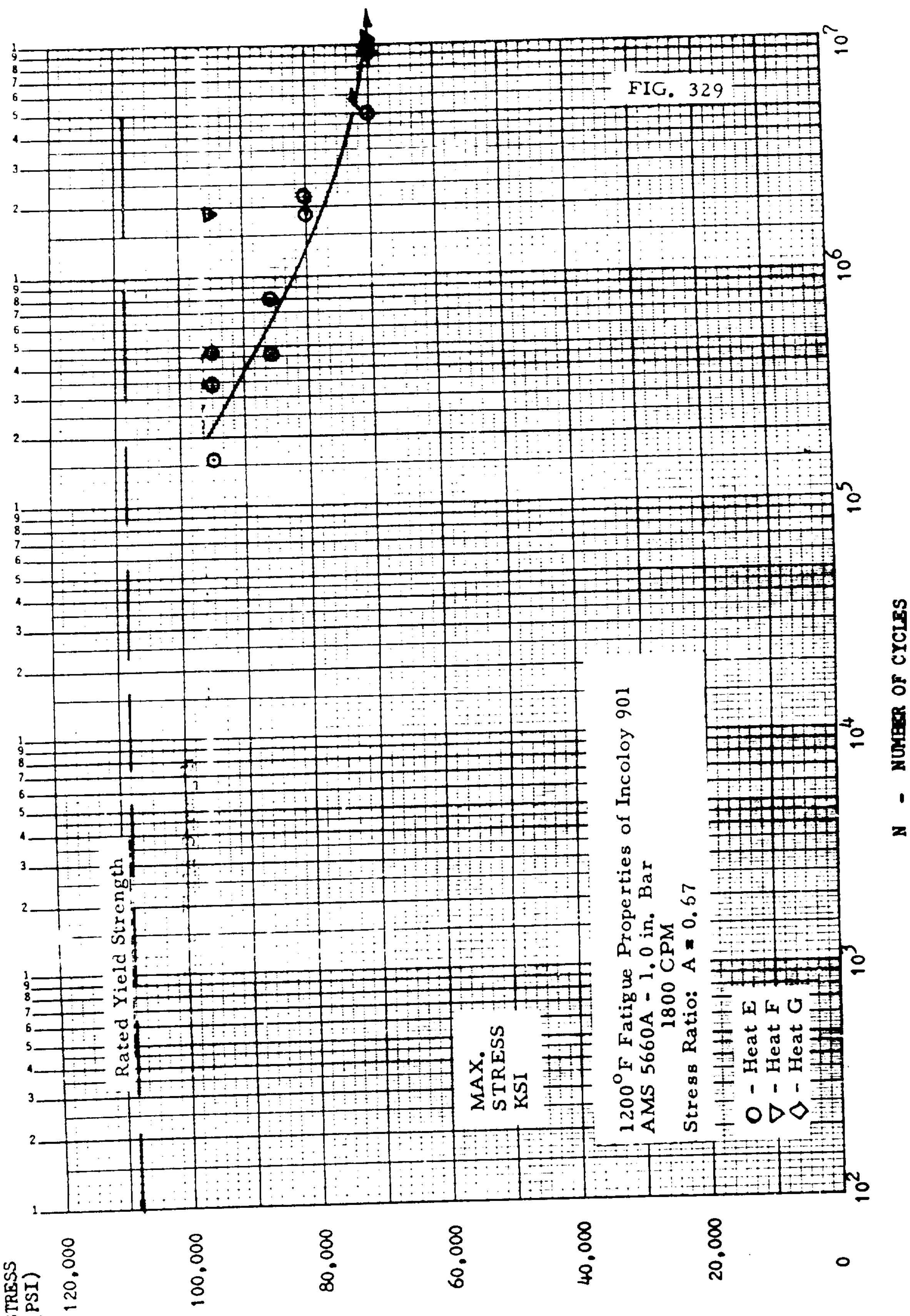


FIG. 329
1200°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
1800 CPM
Stress Ratio: A = 0.67
O - Heat E
▽ - Heat F
◇ - Heat G
MAX. STRESS KSI
Rated Yield Strength
STRESS (PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

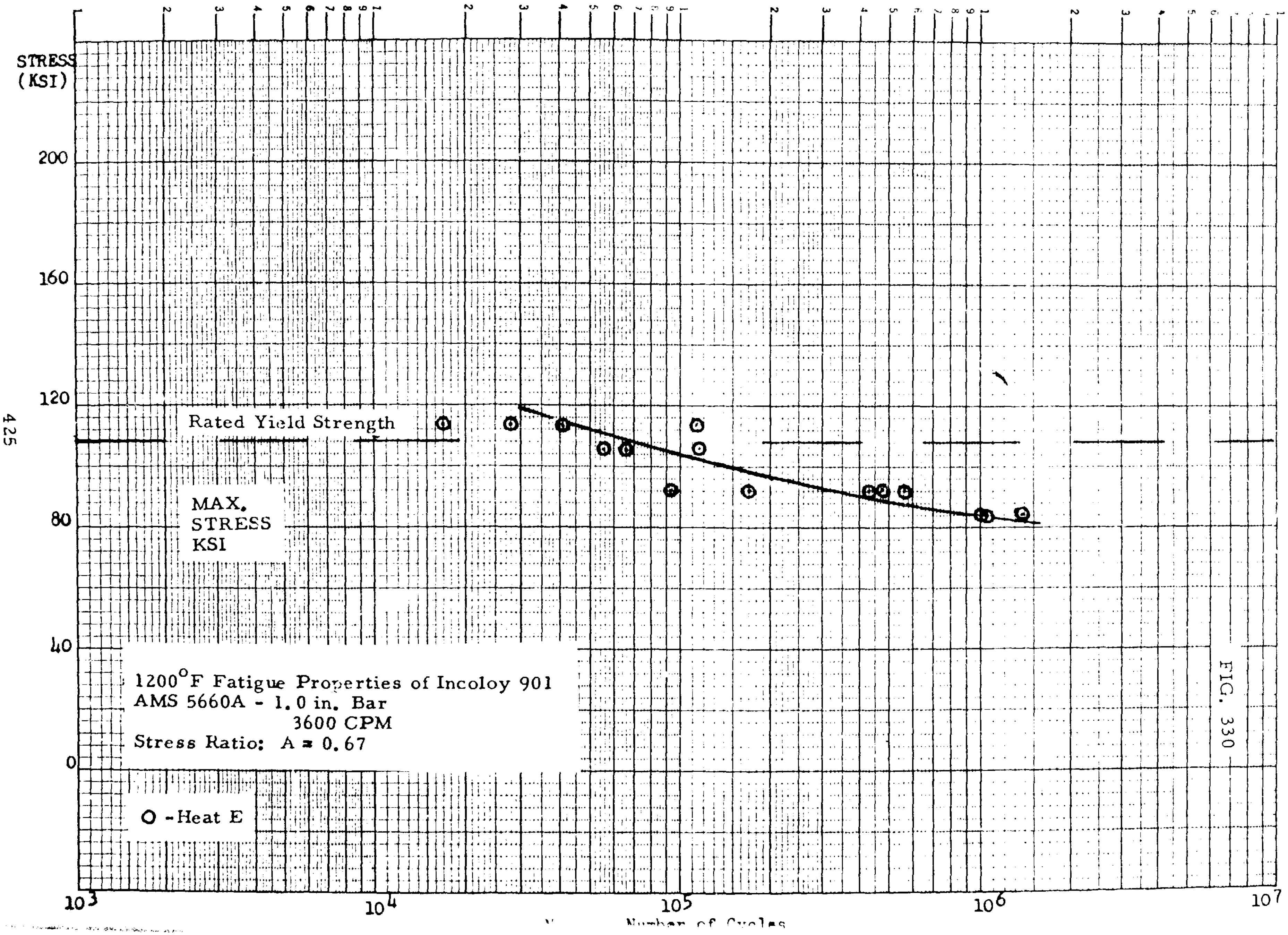
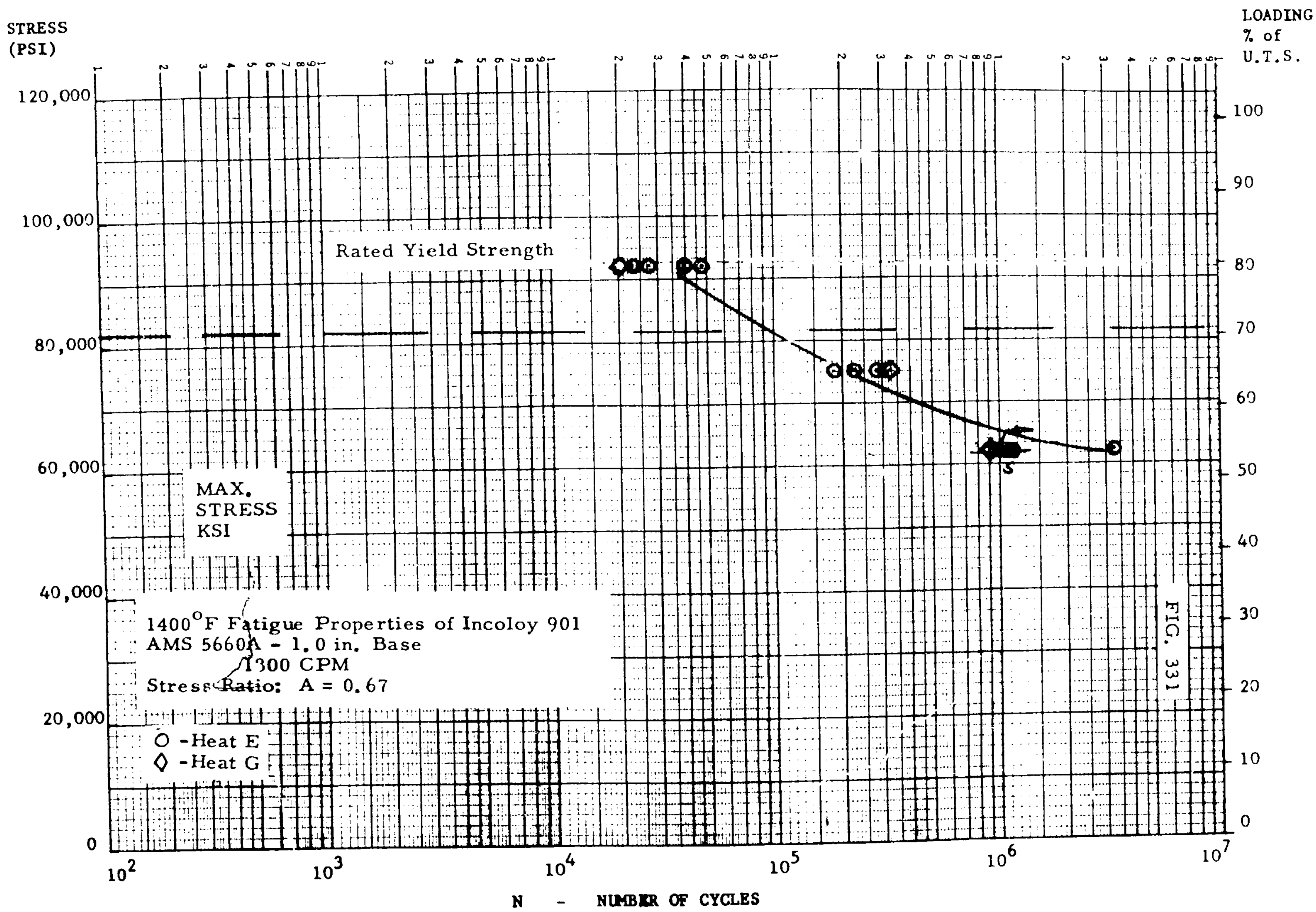
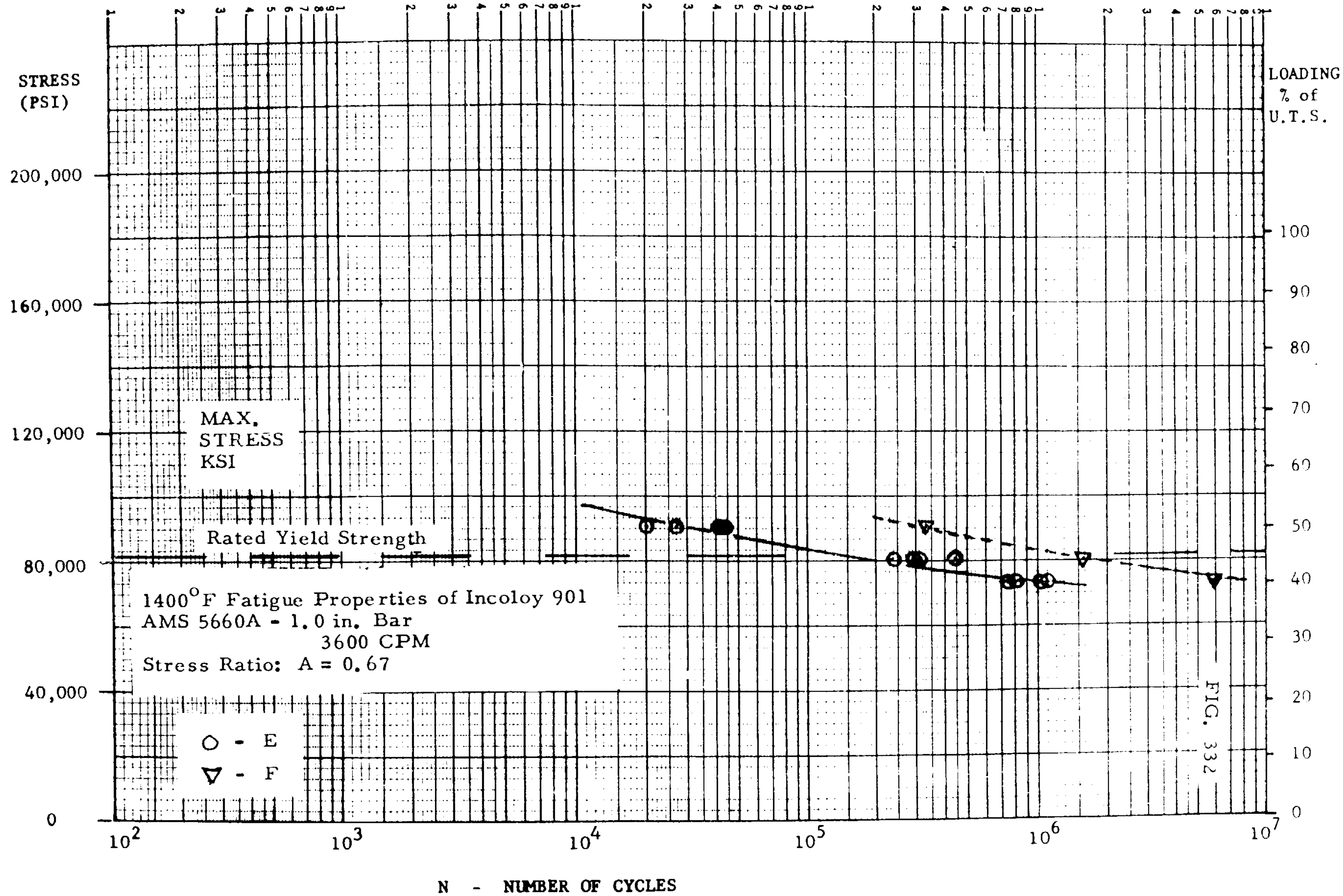

STRESS (KSI)
200
160
120
80
40
0
Rated Yield Strength
MAX. STRESS KSI
1200°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
3600 CPM
Stress Ratio: A = 0.67
O -Heat E
10^3
10^4
10^5
10^6
10^7
Number of Cycles

FIG. 330

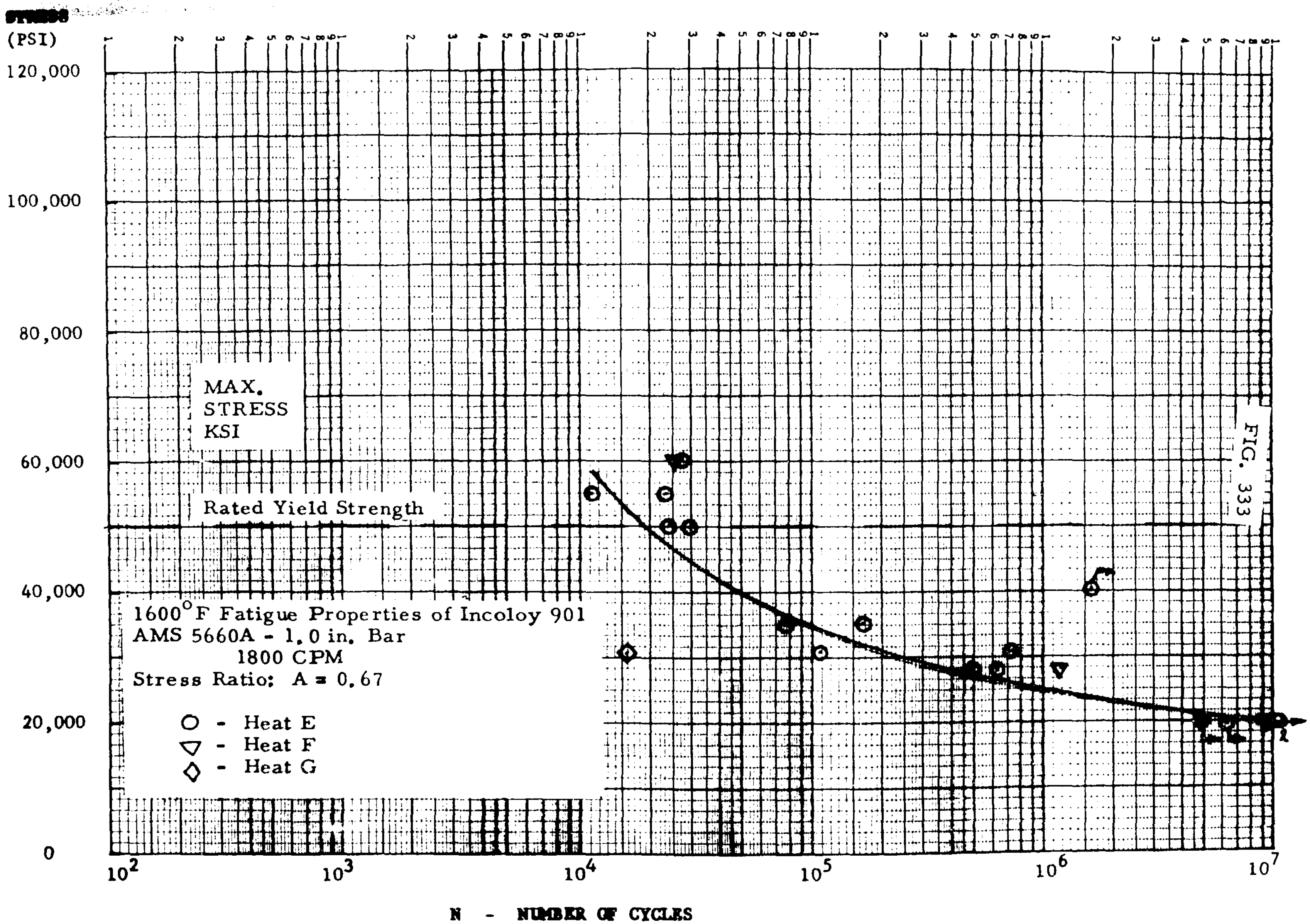


STRESS (PSI)
LOADING % of U.T.S.
Rated Yield Strength
MAX. STRESS KSI
1400°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Base
1300 CPM
Stress Ratio: A = 0.67
○ -Heat E
◇ -Heat G
FIG. 331
N - NUMBER OF CYCLES



STRESS (PSI)
200,000
160,000
120,000
80,000
40,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
MAX. STRESS KSI
Rated Yield Strength
1400°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
3600 CPM
Stress Ratio: A = 0.67
○ - E
▽ - F
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 332



(PSI)
120,000
100,000
80,000
60,000
40,000
20,000
0
MAX.
STRESS
KSI
Rated Yield Strength
1600°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
1800 CPM
Stress Ratio: A = 0.67
○ - Heat E
▽ - Heat F
◇ - Heat G
FIG. 333
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

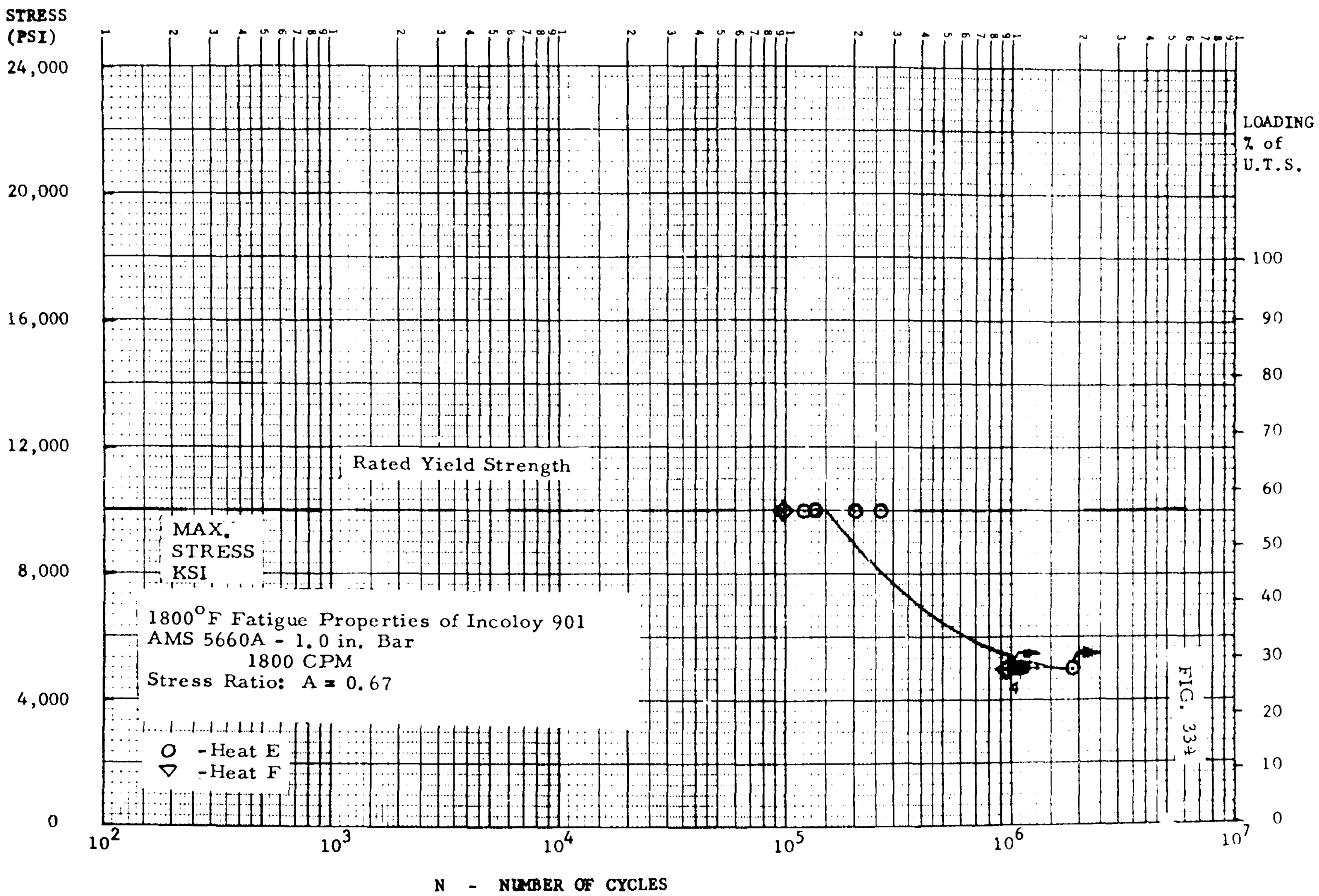

STRESS (PSI)
24,000
20,000
16,000
12,000
8,000
4,000
0
LOADING % of U.T.S.
100
90
80
70
60
50
40
30
20
10
0
Rated Yield Strength
MAX. STRESS KSI
1800°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
1800 CPM
Stress Ratio: A = 0.67
O -Heat E
▽ -Heat F
10^2
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 334

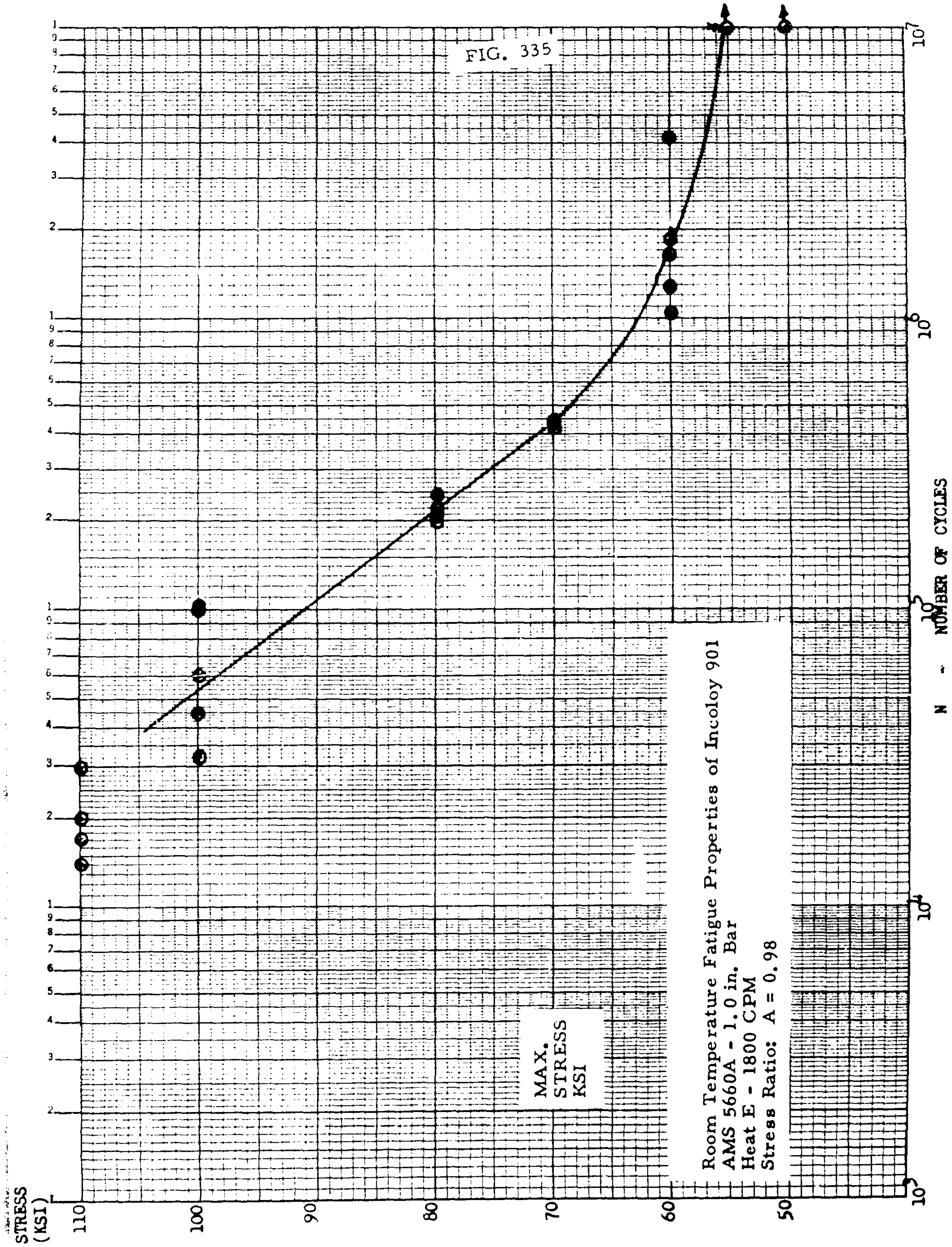
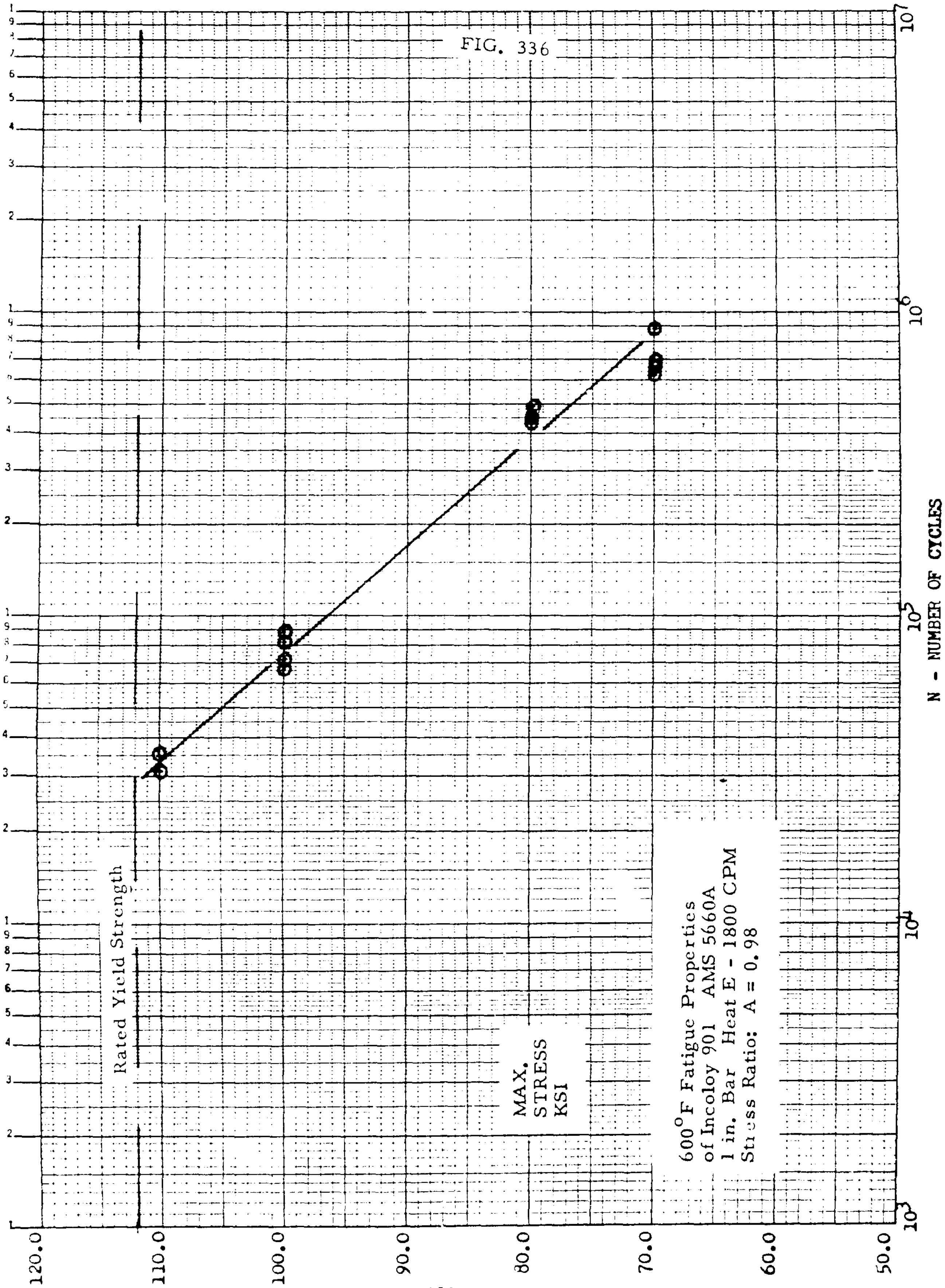


FIG. 335
Room Temperature Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.98
MAX. STRESS KSI
N - NUMBER OF CYCLES
STRESS (KSI)
110
100
90
80
70
60
50
10^3
10^4
10^5
10^6
10^7

FIG. 336



Rated Yield Strength
MAX.
STRESS
KSI
600°F Fatigue Properties
of Incoloy 901 AMS 5660A
1 in. Bar Heat E - 1800 CPM
Stress Ratio: A = 0.98
N - NUMBER OF CYCLES
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
10^3
10^4
10^5
10^6
10^7

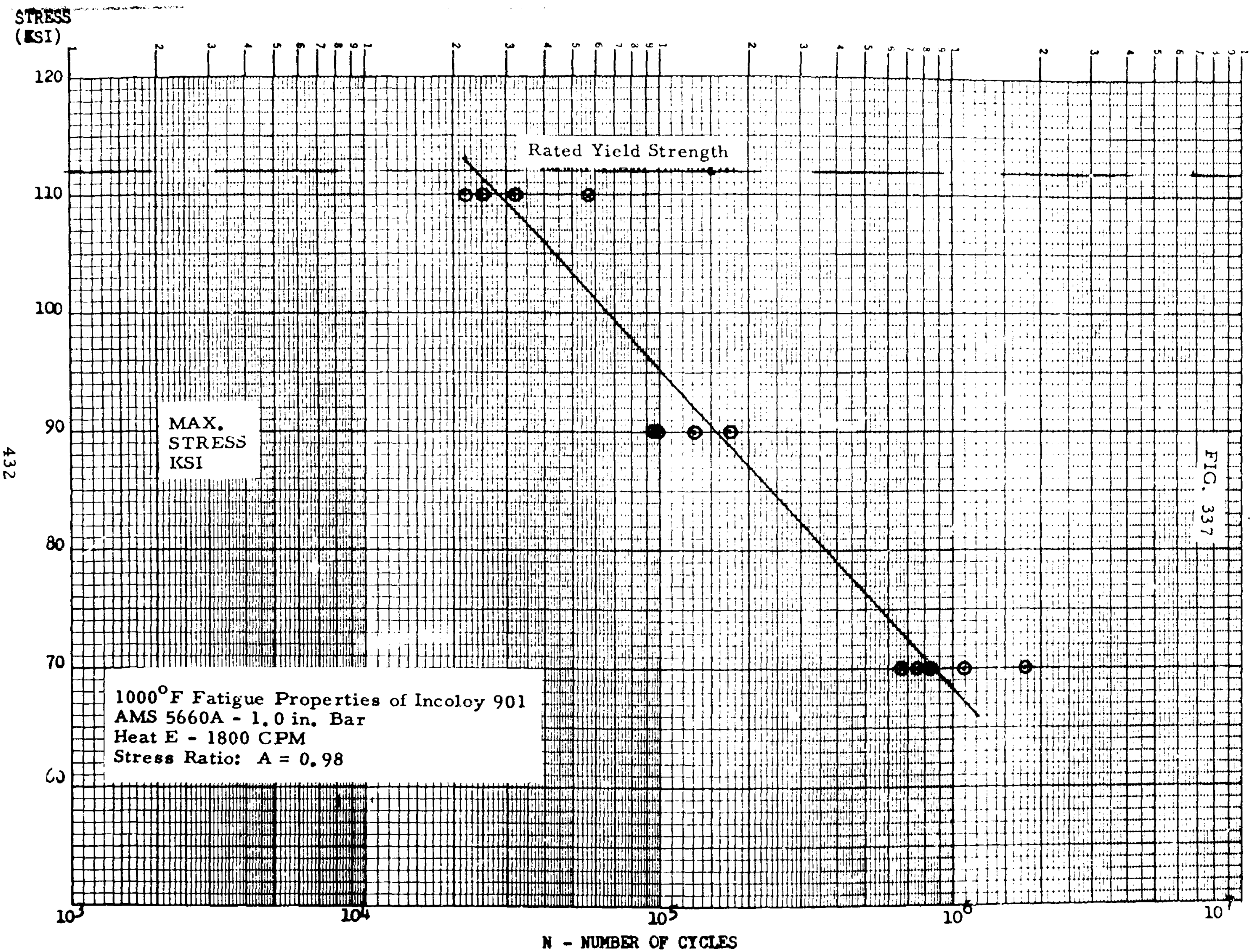


FIG. 337
1000°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.98
Rated Yield Strength
MAX. STRESS KSI
STRESS (KSI)
120
110
100
90
80
70
60
N - NUMBER OF CYCLES
10^3
10^4
10^5
10^6
10^7

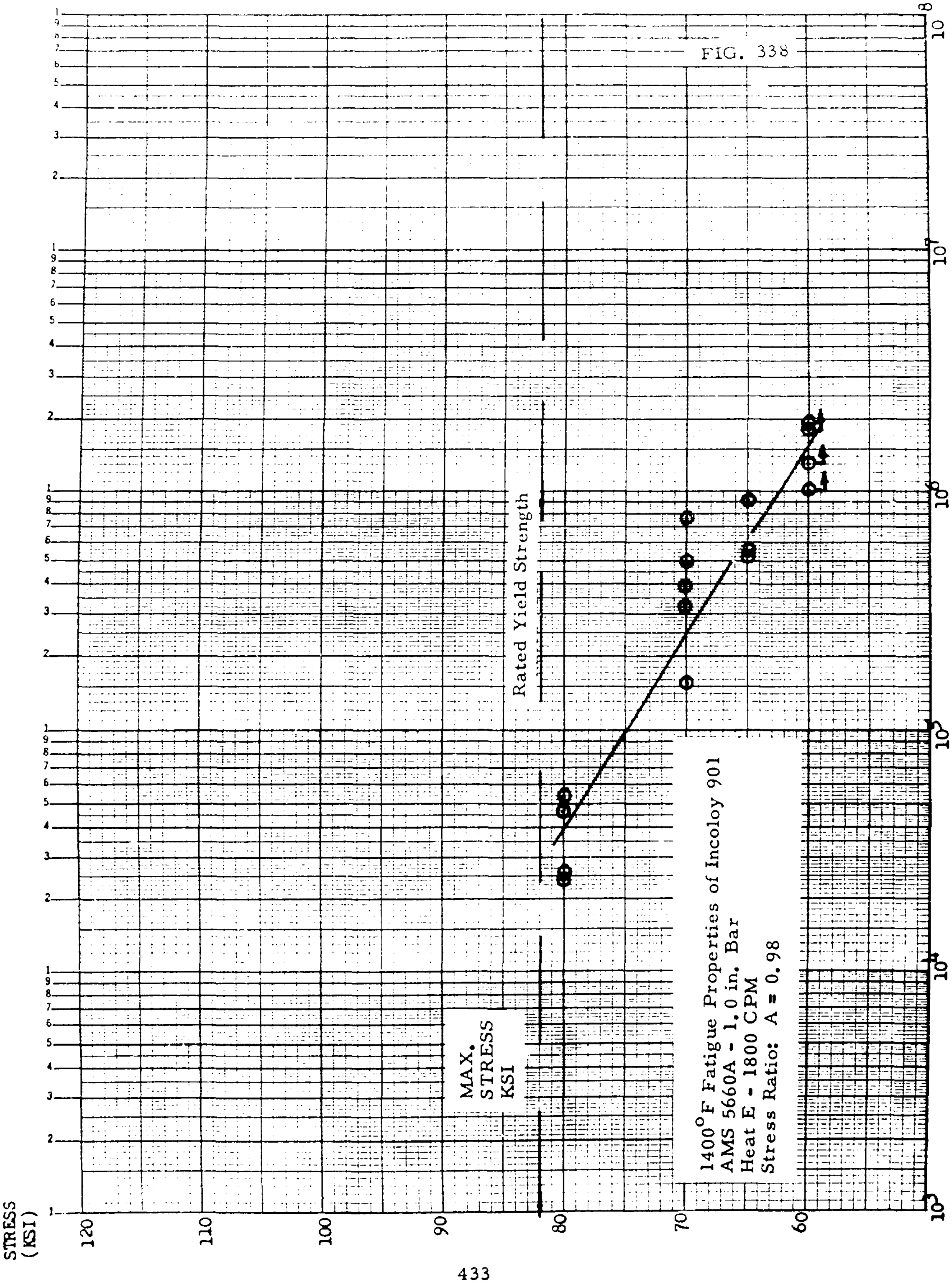


FIG. 338
1400°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.98
MAX. STRESS KSI
Rated Yield Strength
STRESS (KSI)
120
110
100
90
80
70
60
NUMBER OF CYCLES
10^3
10^4
10^5
10^6
10^7
10^8

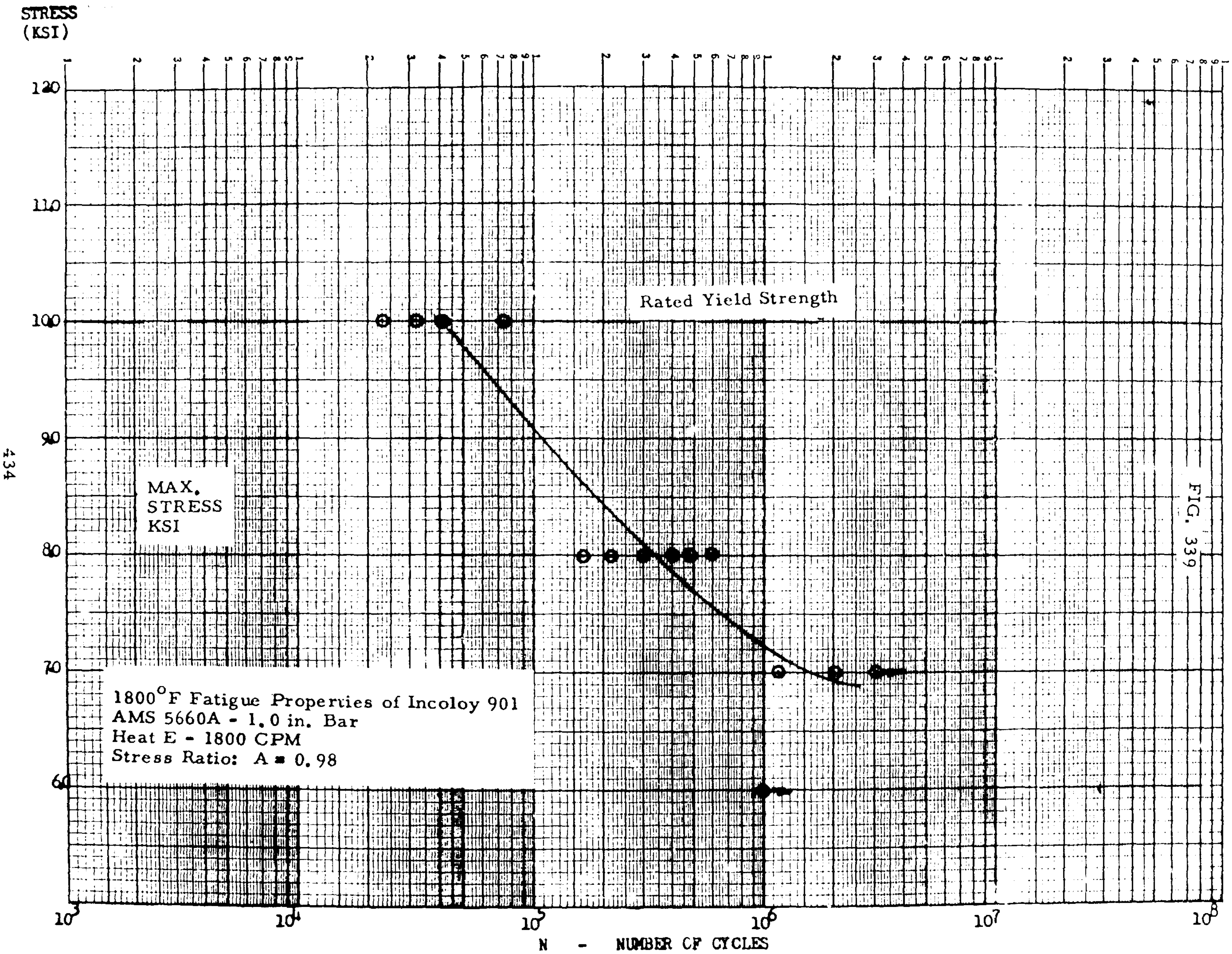

STRESS (KSI)
120
110
100
90
80
70
60
Rated Yield Strength
MAX. STRESS KSI
1800°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 0.98
10^3
10^4
10^5
10^6
10^7
10^8
N - NUMBER OF CYCLES

FIG. 339

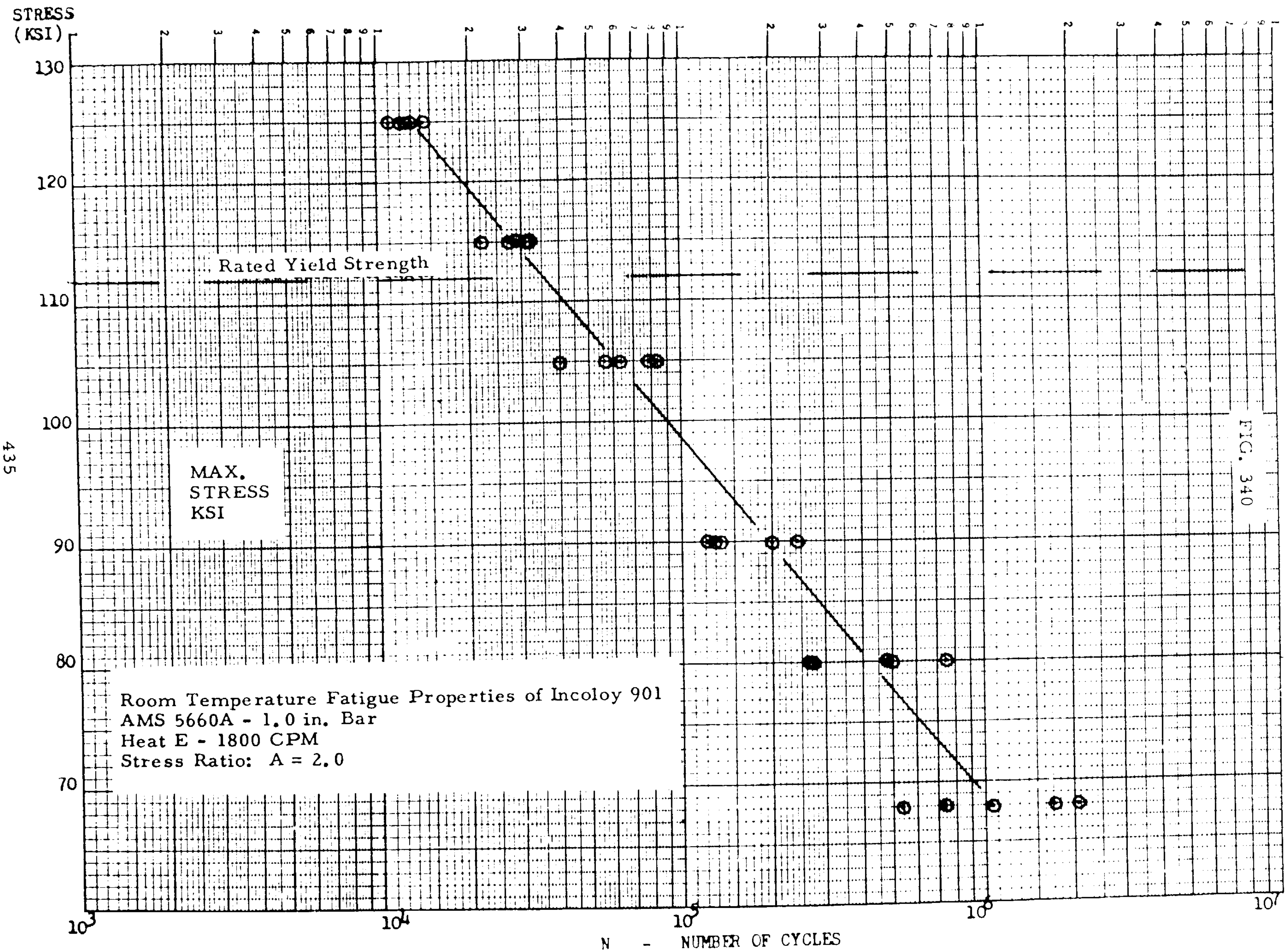
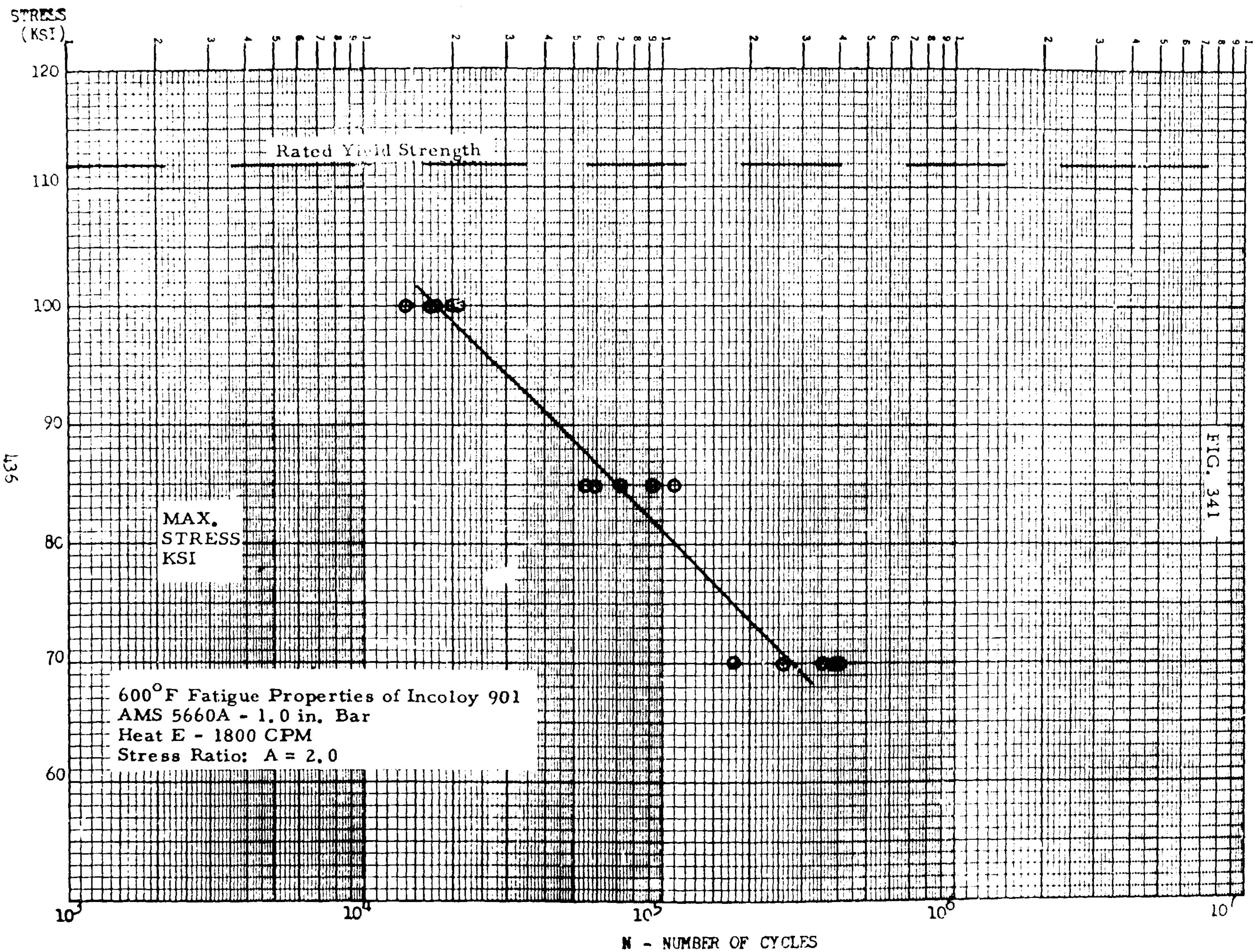

STRESS (KSI)
130
120
110
100
90
80
70
Rated Yield Strength
MAX. STRESS KSI
Room Temperature Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 2.0
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES
FIG. 340

FIG. 341



STRESS (KSI)
120
110
100
90
80
70
60
Rated Yield Strength
MAX. STRESS KSI
600°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 2.0
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

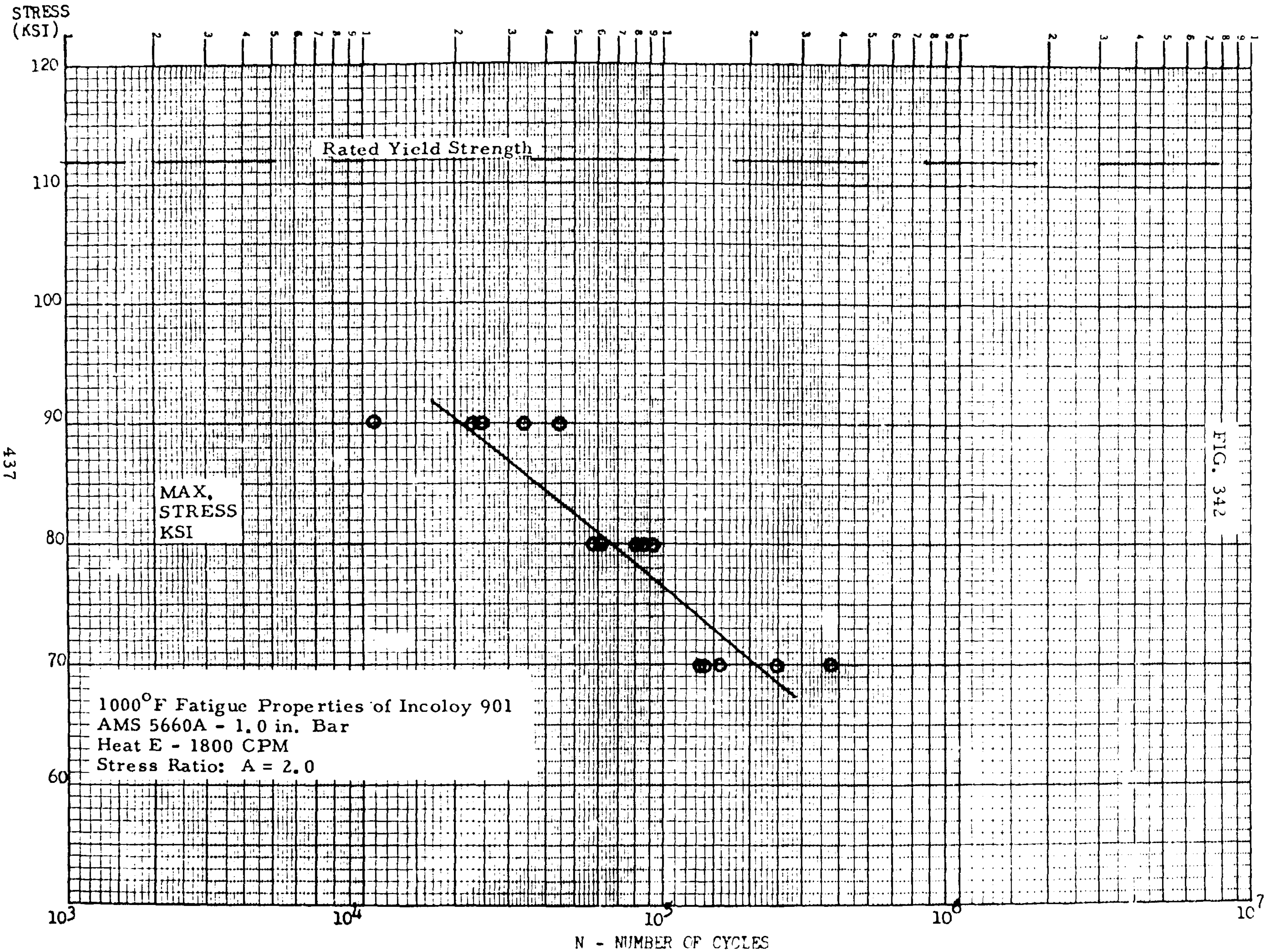

STRESS (KSI)
120
110
100
90
80
70
60
Rated Yield Strength
MAX. STRESS KSI
1000°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 2.0
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES

FIG. 342

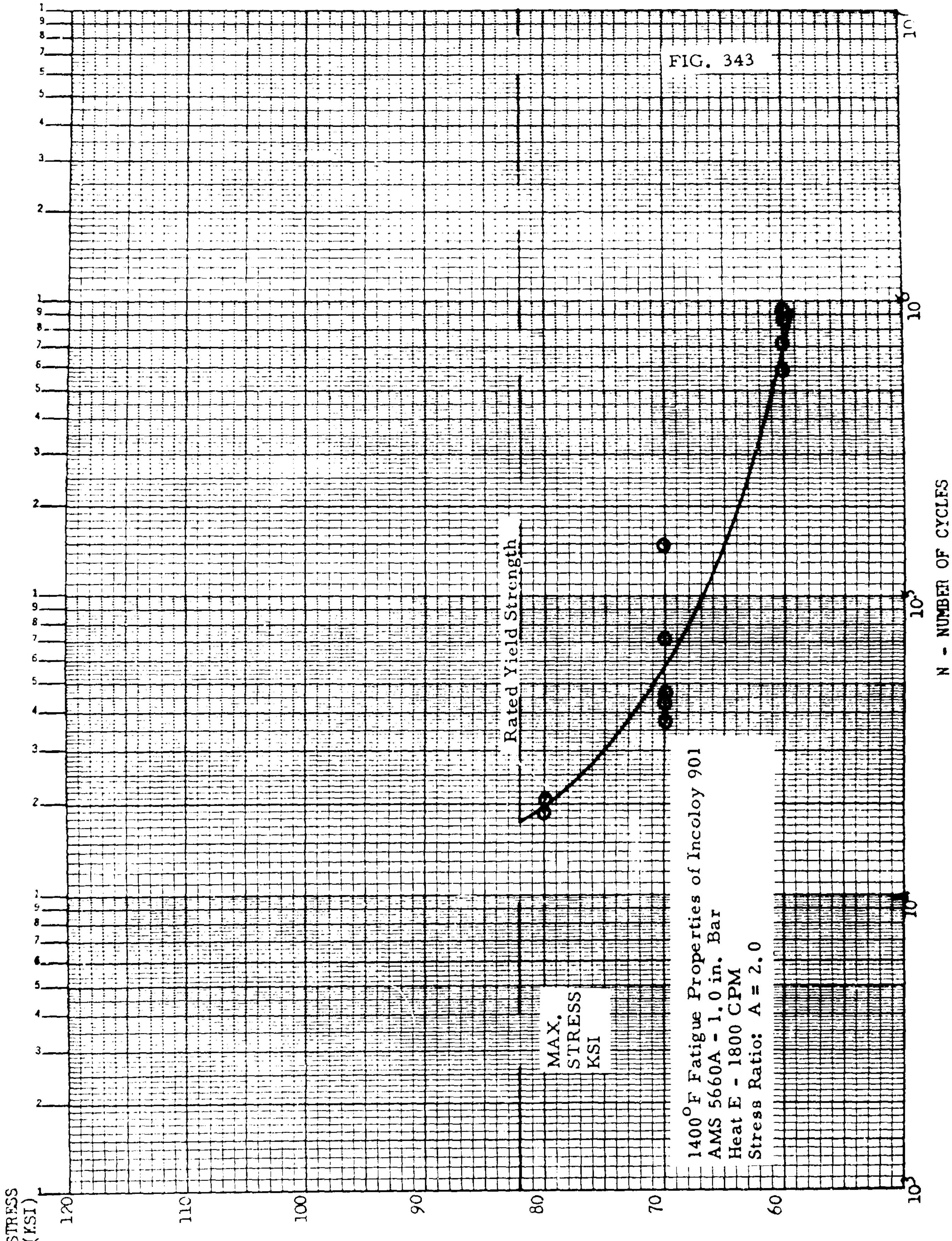
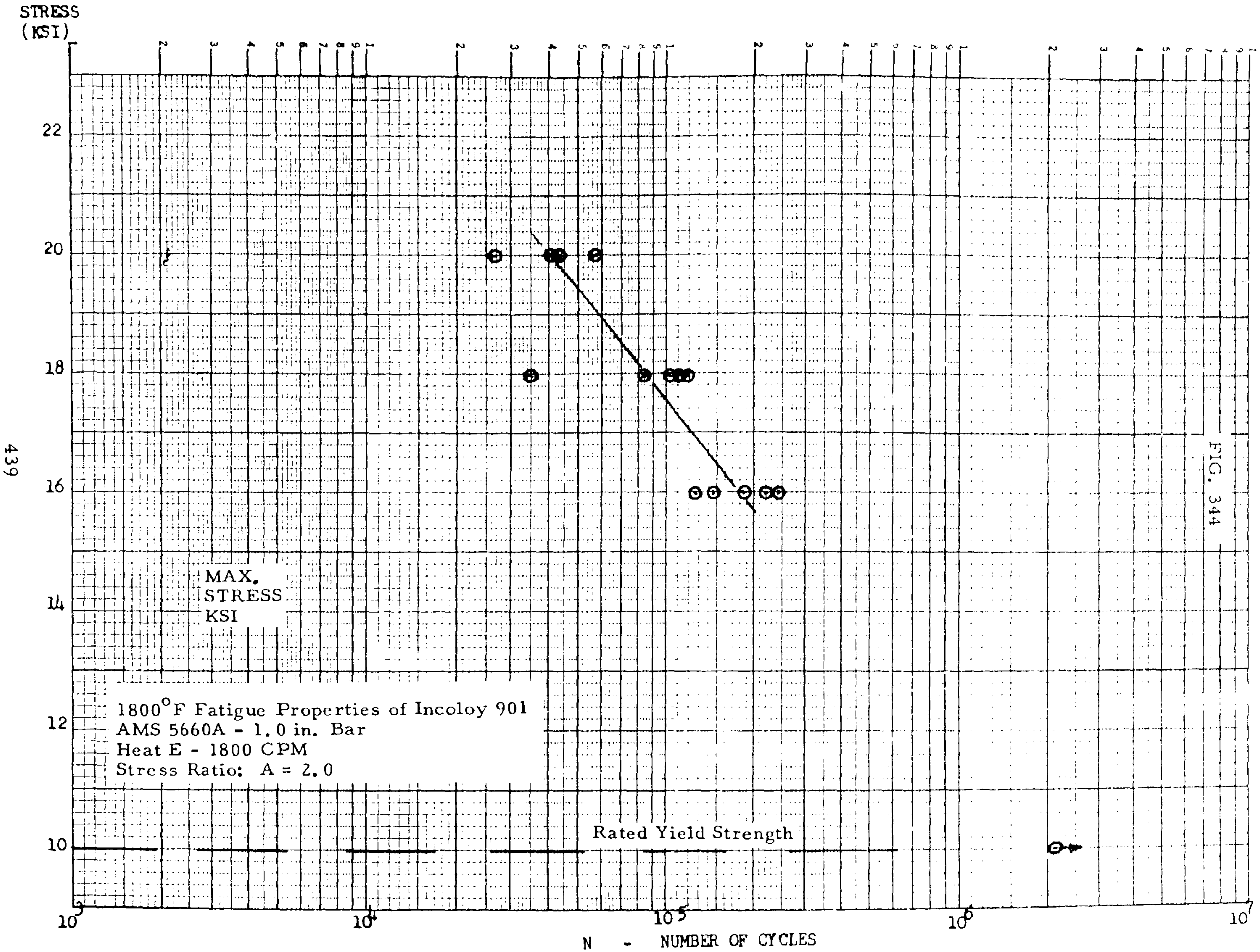


FIG. 343
1400°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 2.0
Rated Yield Strength
MAX. STRESS KSI
STRESS (KSI)
120
110
100
90
80
70
60
N - NUMBER OF CYCLES
10^3
10^4
10^5
10^6
10^7


STRESS
(KSI)
22
20
18
16
14
12
10
MAX.
STRESS
KSI
1800°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = 2.0
Rated Yield Strength
10^3
10^4
10^5
10^6
10^7
N - NUMBER OF CYCLES
FIG. 344

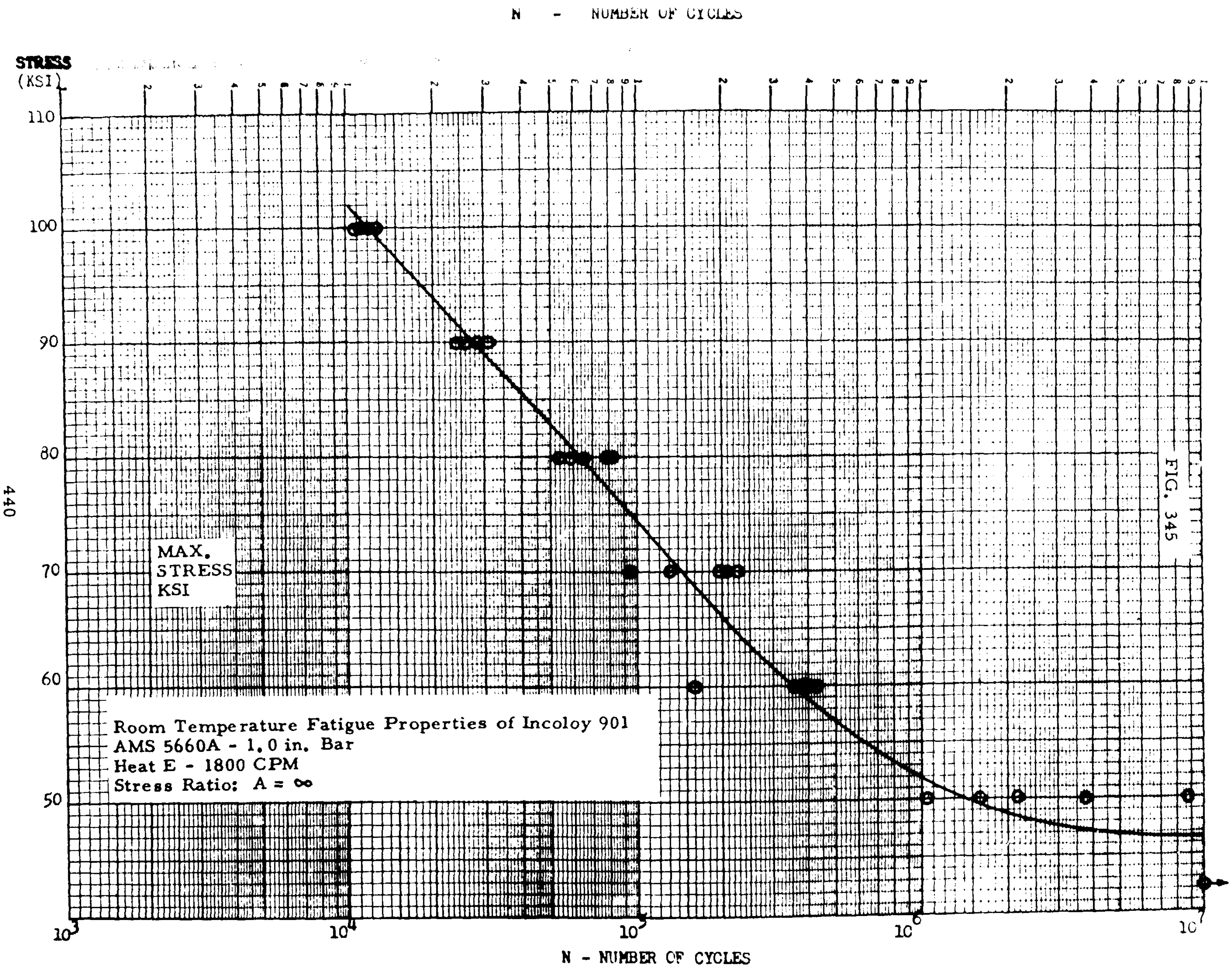

N - NUMBER OF CYCLES
STRESS (KSI)
MAX. STRESS KSI
Room Temperature Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = ∞
N - NUMBER OF CYCLES

FIG. 345

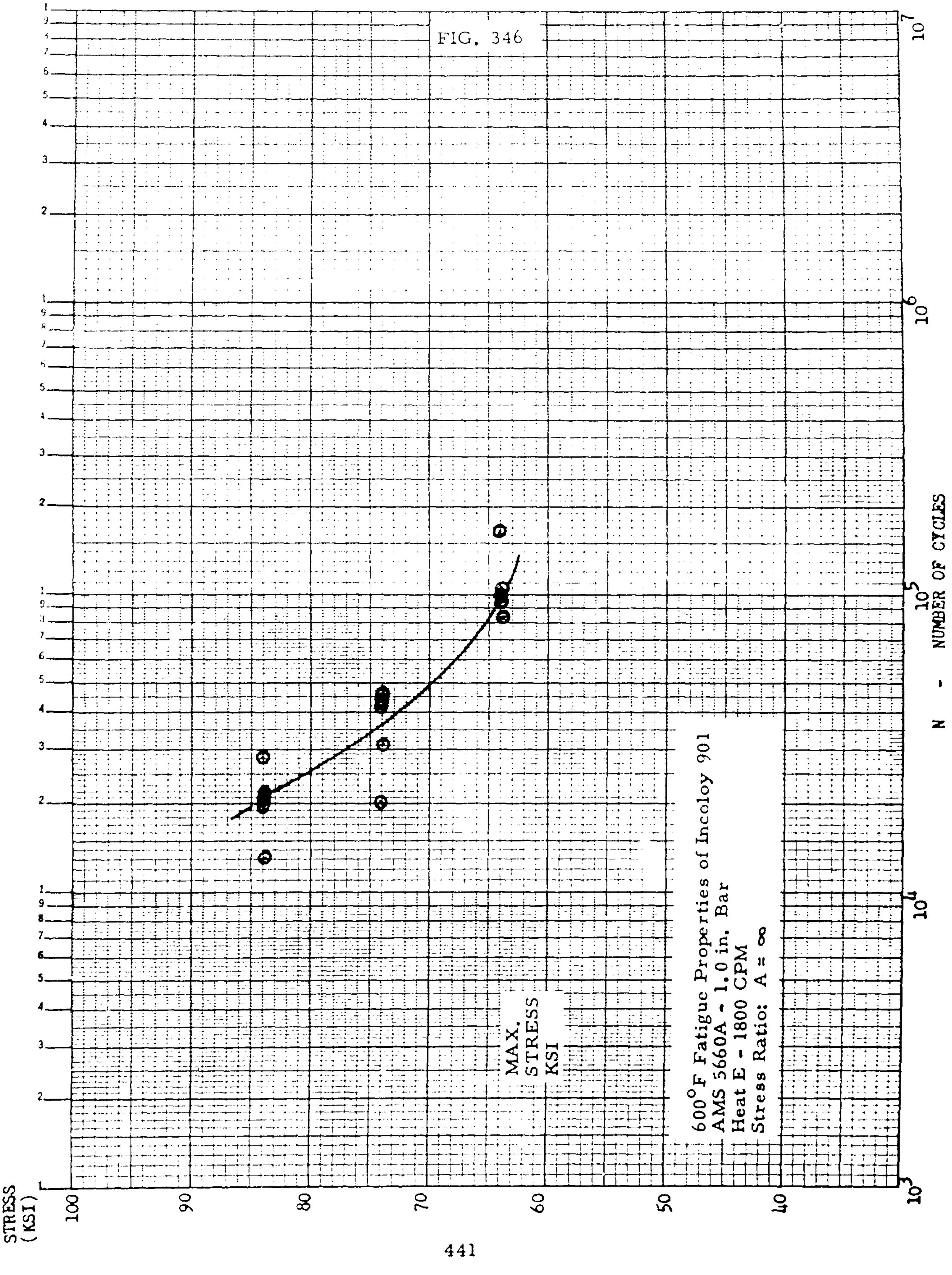
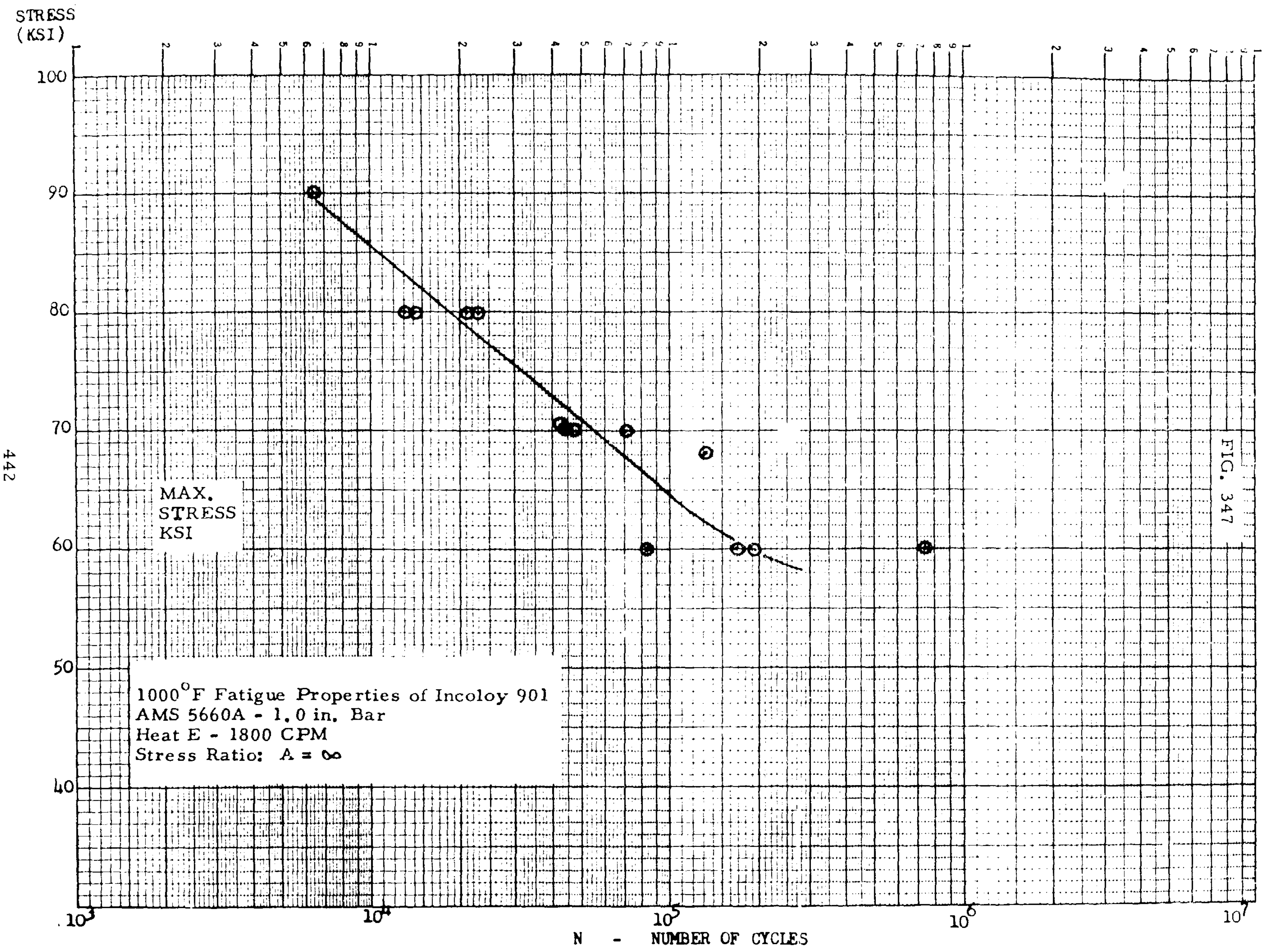


FIG. 346
600°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = ∞
MAX. STRESS KSI
STRESS (KSI)
N - NUMBER OF CYCLES
100
90
80
70
60
50
40
10^3
10^4
10^5
10^6
10^7

FIG. 347


STRESS (KSI)
100
90
80
70
60
50
40
MAX. STRESS KSI
1000°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = ∞
10³
10⁴
10⁵
10⁶
10⁷
N - NUMBER OF CYCLES

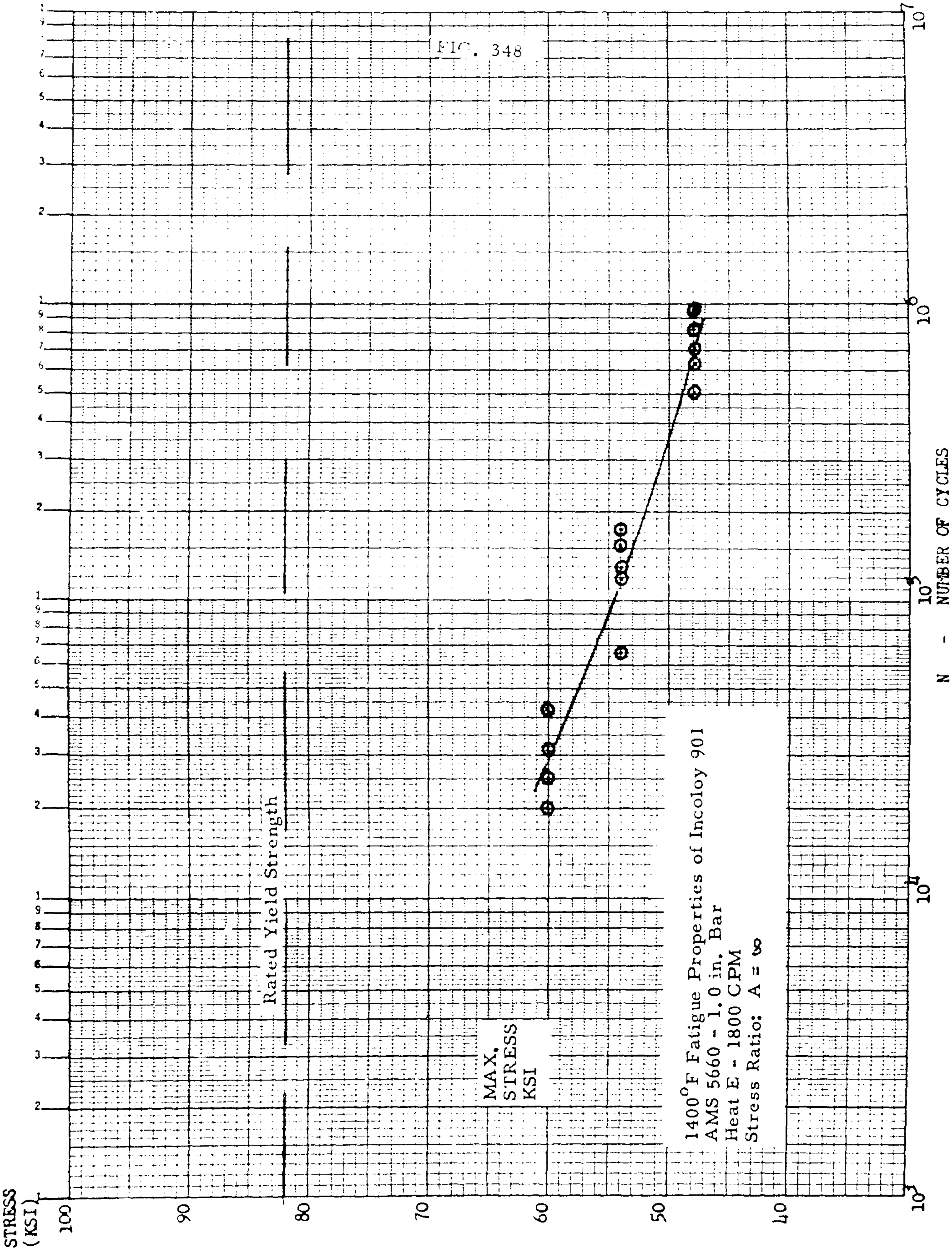
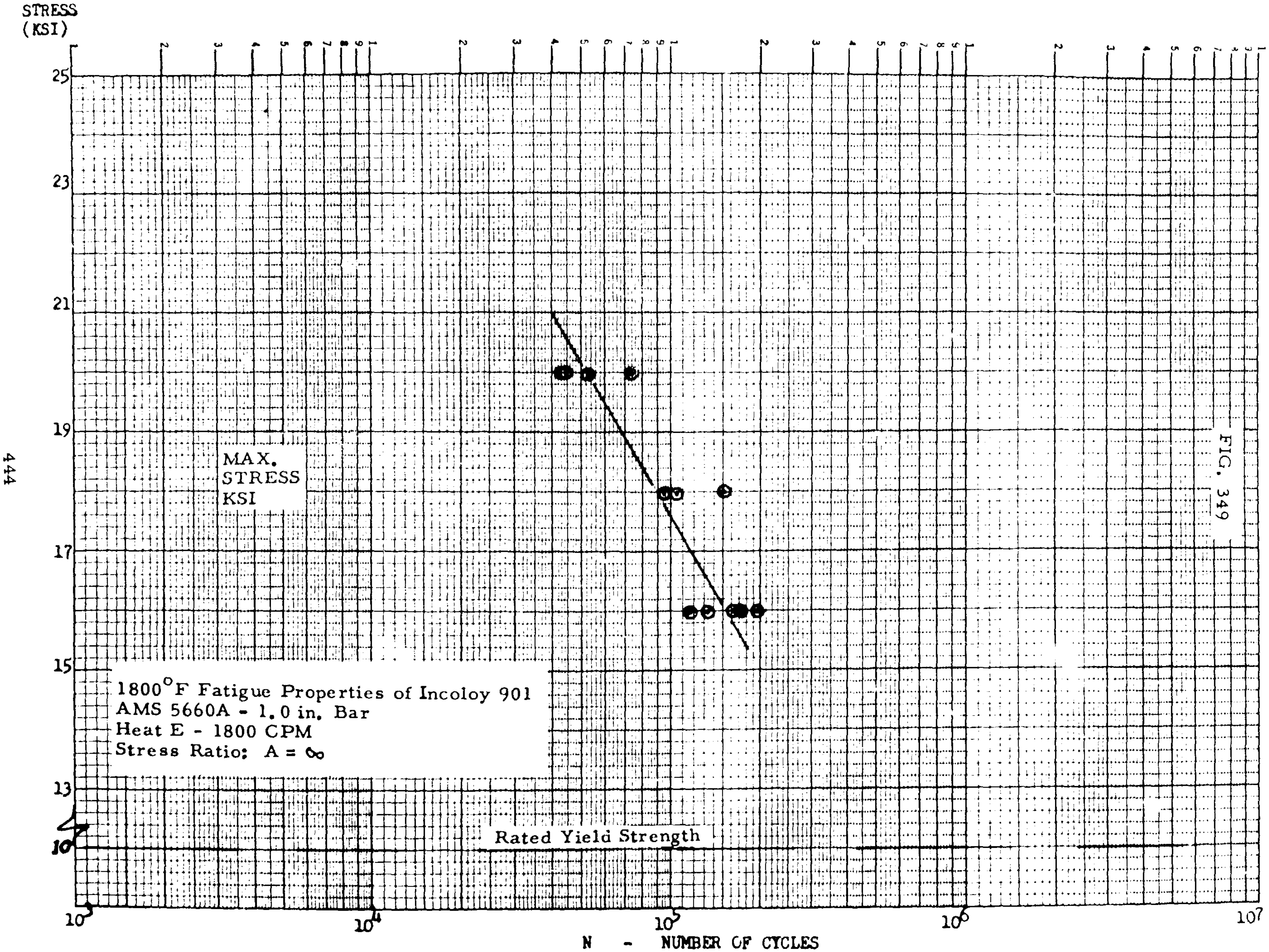


FIG. 348
Rated Yield Strength
MAX. STRESS KSI
1400°F Fatigue Properties of Incoloy 901
AMS 5660 - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = ∞
N - NUMBER OF CYCLES
STRESS (KSI)
100
90
80
70
60
50
40
10³
10⁴
10⁵
10⁶
10⁷

FIG. 349



STRESS (KSI)
MAX. STRESS KSI
1800°F Fatigue Properties of Incoloy 901
AMS 5660A - 1.0 in. Bar
Heat E - 1800 CPM
Stress Ratio: A = ∞
Rated Yield Strength
N - NUMBER OF CYCLES

FIG. 350

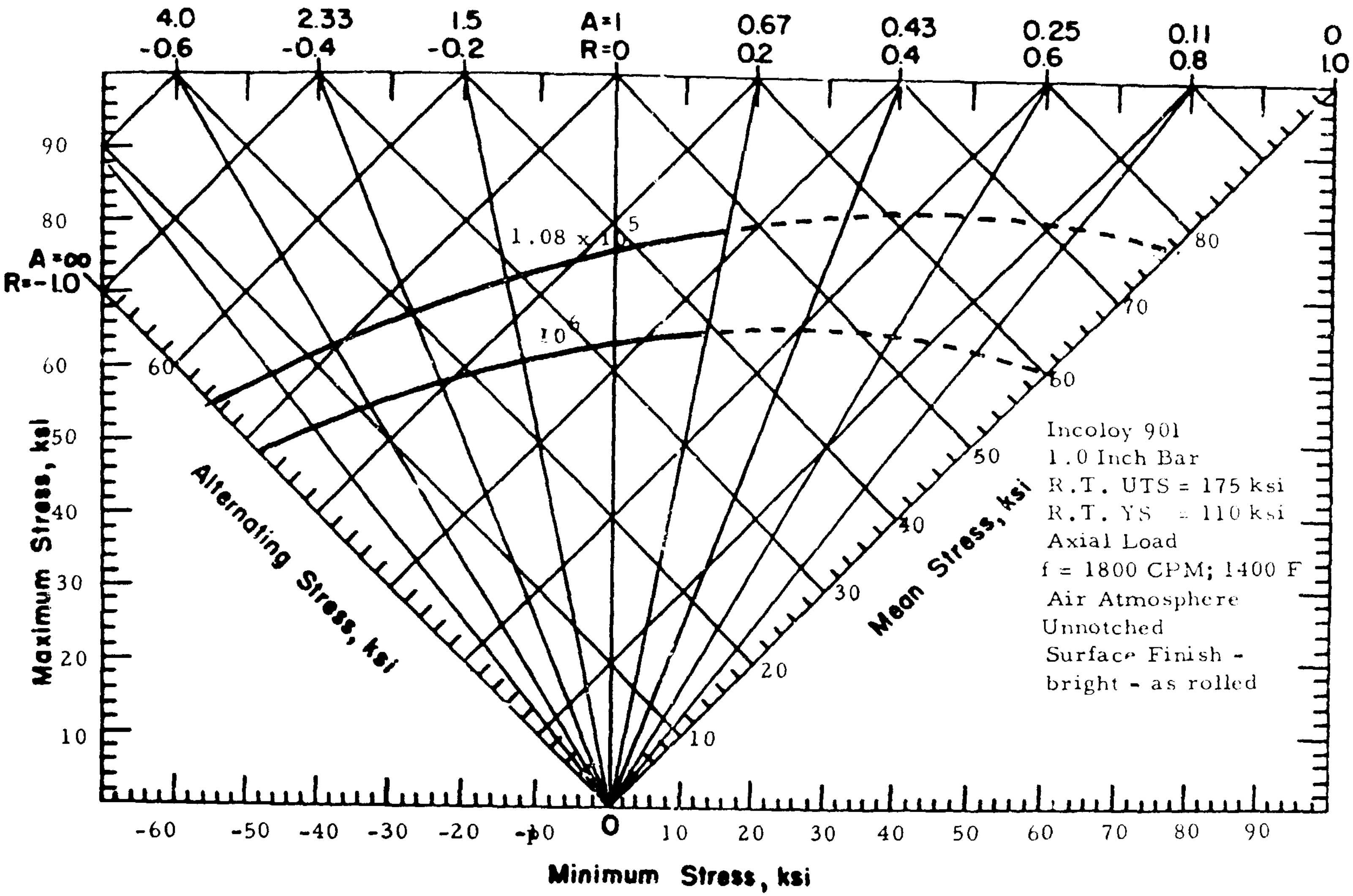


FIGURE
TYPICAL CONSTANT LIFE DIAGRAM FOR FATIGUE BEHAVIOR OF INCOLOY 901 BAR MATERIAL AT 1400 F.

SECTION VIII - MIL-HDB-5 DATA PRESENTATION

8.1 MATERIAL, RENE' 41

TABLE DESIGN MECHANICAL AND PHYSICAL PROPERTIES OF

Alloy	Rene' 41				
Form	Foil ($t \leq .020"$)				
Condition	Solution Treated and Aged*				
DIRECTION	L		T		
Basis	A	B	A	B	
Mechanical Properties					
F_{tu}, ksi	177.7	184.8	176.6	183.7	
F_{ty}, ksi	120.3	125.1	122.8	127.7	
F_{cy}, ksi					
F_{su}, ksi					
F_{bru}, ksi					
(e/D = 1.5)					
(e/D = 2.0)					
F_{bry}, ksi					
(e/D = 1.5)					
(e/D = 2.0)					
e, per cent					
E, 10^6 psi	31.6				
E_c, 10^6 psi					
G, 10^6 psi					
Physical Properties					
ω, lb/in.^{3}					
C, Btu/(lb)(F)					
K, Btu/[(hr)(ft^2)(F)/ft]					
α, 10^{-6} in./in./F					

* Solution Treat - 1975°F for 1/2-hour - Water Quench
Age - 1400°F for 16-hours - Air Cool

TABLE DESIGN MECHANICAL AND PHYSICAL PROPERTIES OF

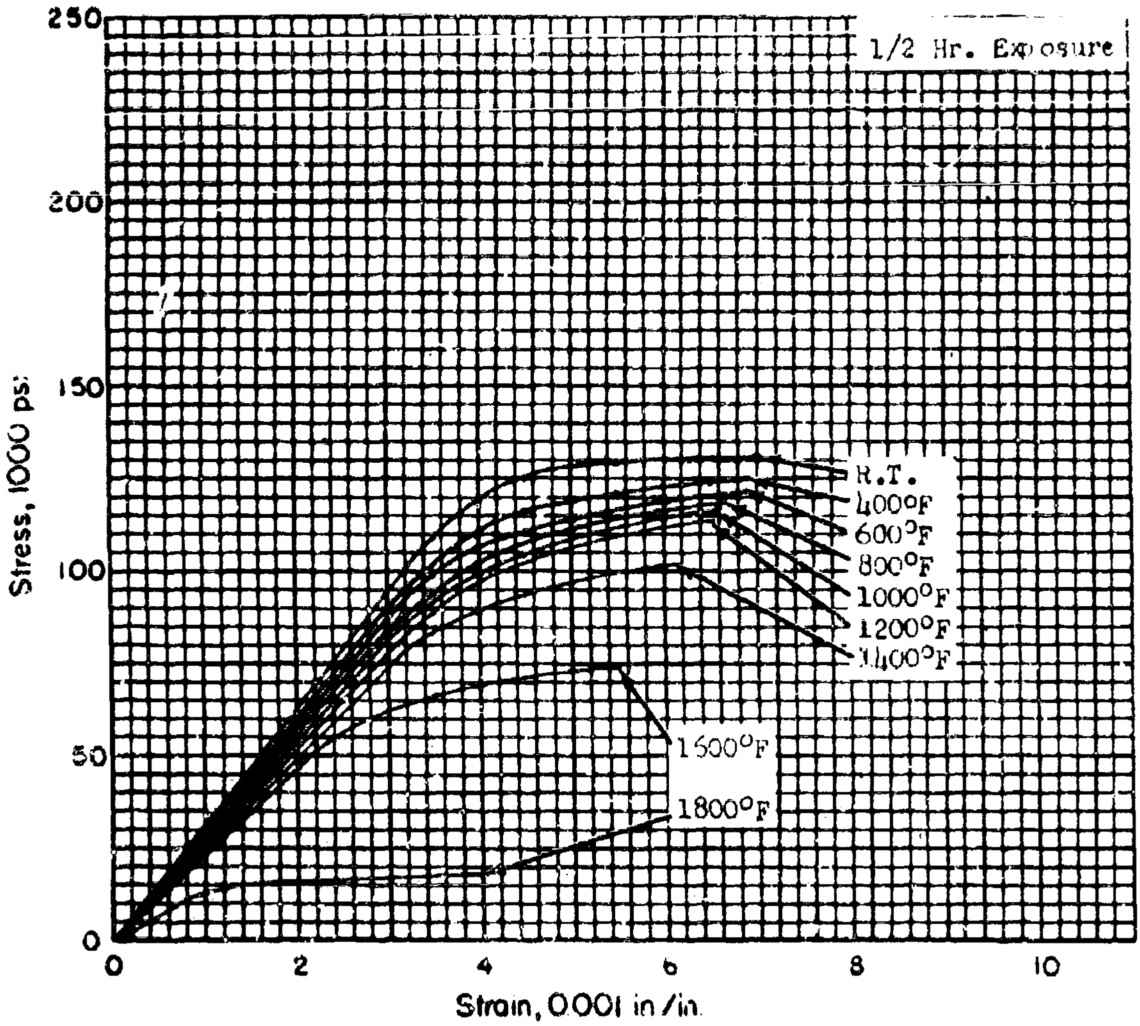
Alloy	Rene' 41			
Form	Sheet (.020" $\leq$ t $\leq$ .187)			
Condition	Solution treated and aged*			
Direction	L		T	
Basis	A	B	A	B
Mechanical Properties				
F_{tu}, ksi	177.5	185.6	177.7	185.8
F_{ty}, ksi	123.0	133.3	123.6	134.0
F_{cy}, ksi	146.4	154.4	137.1	148.6
F_{su}, ksi	118.8	122.1	112.8	118.0
F_{bru}, ksi				
(e/D = 1.5)	269.3	276.9	257.7	269.4
(e/D = 2.0)	331.2	340.6	323.7	338.5
F_{bry}, ksi				
(e/D = 1.5)	200.6	232.6	196.2	213.0
(e/D = 2.0)	269.3	284.0	261.5	275.7
e, per cent				
E, 10^6 psi	31.6			
E_c, 10^6 psi	31.6			
G, 10^6 psi				
Physical Properties				
ω, lb/in.^{3}				
C, Btu/(lb)(F)				
K, Btu/[(hr)(ft^2)(F)/ft]				
α, 10^{-6} in./in./F				

Note: Solution treat 1975 F for 1/2 hour, water quench
Age 1400 F for 16 hours. Air cool.

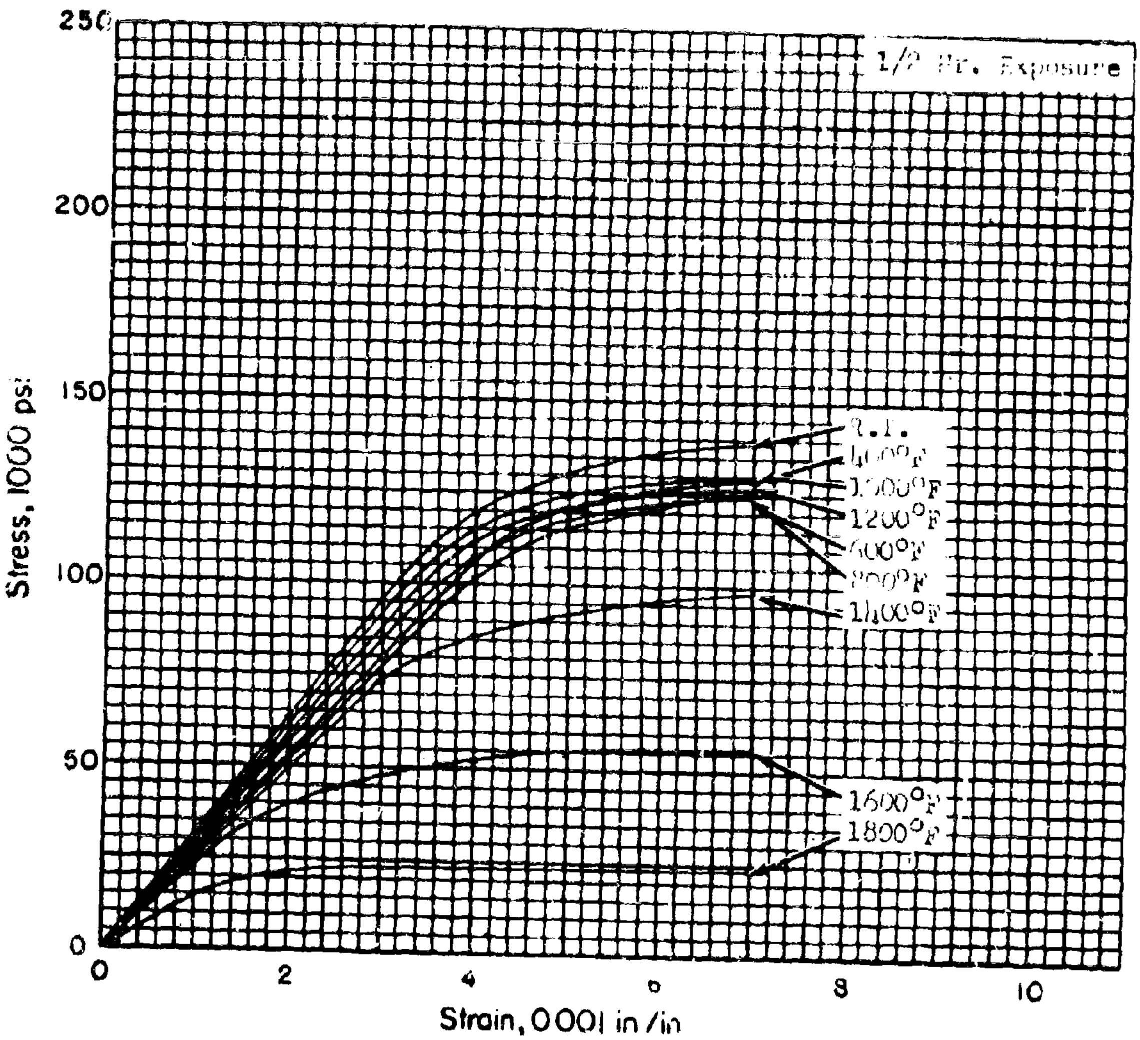
TABLE DESIGN MECHANICAL AND PHYSICAL PROPERTIES OF

Alloy	Rene' 41							
Form	Plate, Bar & Forgings		Plate & Forging ‡				Bar	
Condition	Solution Treated and Aged*							
Direction	L		L		T		T	
Basis	Tentative A	Tentative B	Tentative A	Tentative B	Tentative A	Tentative B	Tentative A	Tentative B
Mechanical Properties								
F_{tu}, ksi	189.9	191.7			183.4	185.2		
F_{ty}, ksi	140.0	42.5			135.7	138.1		
F_{cy}, ksi	142.8	145.4			131.6	134.0		
F_{su}, ksi			132.6	133.8	128.9	130.2	126.9	128.1
F_{bru}, ksi								
(e/D = 1.5)					175.5	278.2		
(e/D = 2.0)					353.4	356.8		
F_{bry}, ksi								
(e/D = 1.5)					218.6	222.5		
(e/D = 2.0)					270.8	275.6		
e, per cent								
E, 10^6 psi	31.6							
E_c, 10^6 psi	31.6							
G, 10^6 psi								
Physical Properties								
ω, lb/in.^{3}								
C, Btu/(lb)(F)								
K, Btu/[(hr)(ft^2)(F)/ft]								
α, 10^{-6} in./in./F								

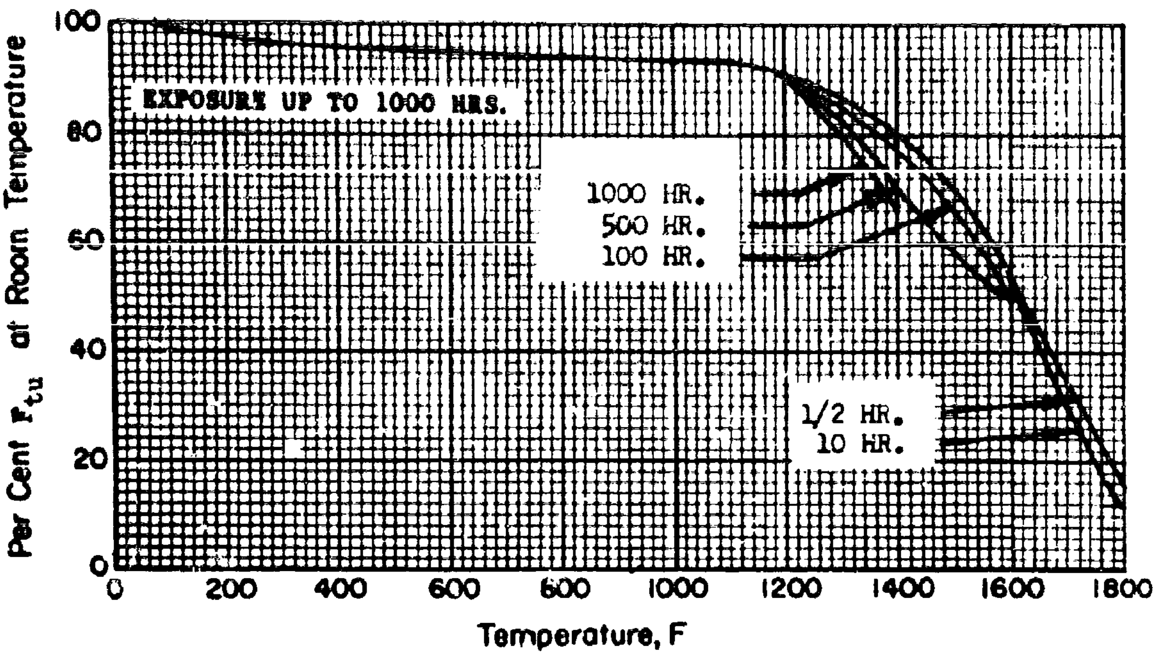
* Solution Treat - 1975oF for 1/2-hour - Water Quench
Age - 1400oF for 16-hours - Air Cool
‡ Bearing Results based on plate only



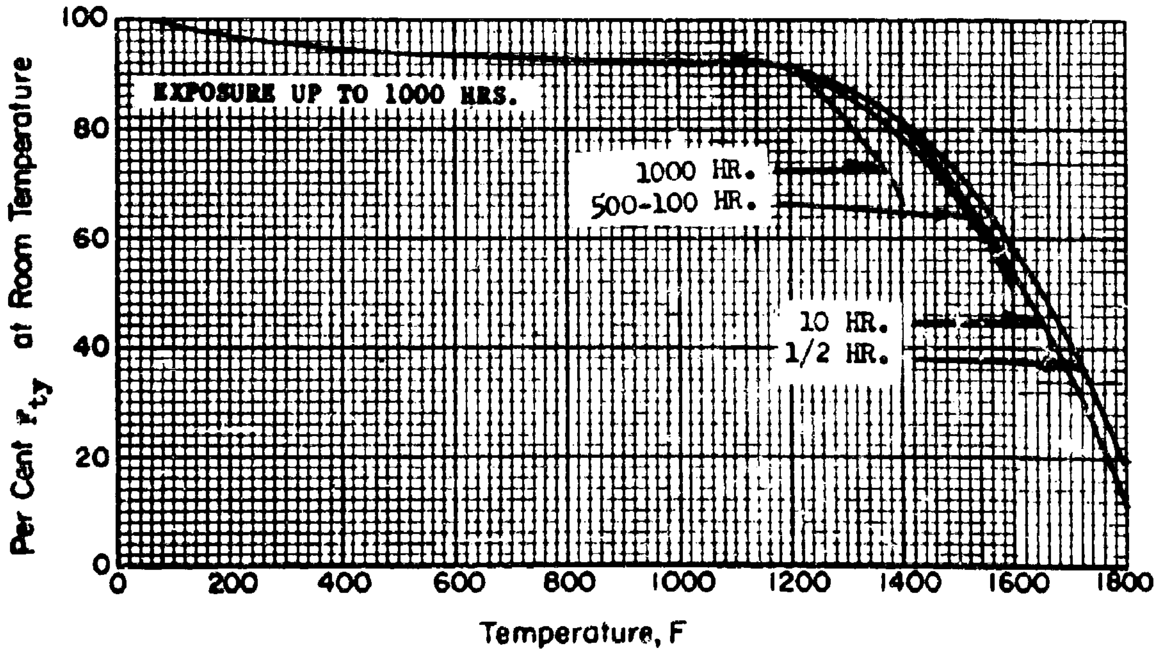
Typical tensile stress versus strain curves for Rene' 41 alloy sheet reduced to 'A' basis. Transverse direction only.



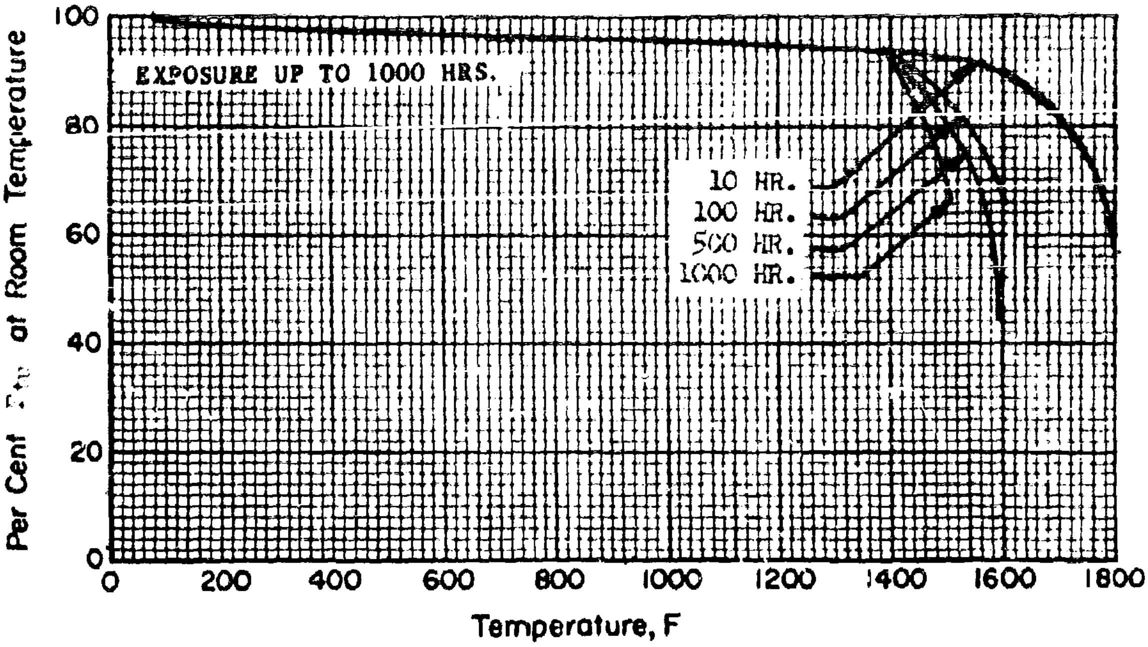
Typical compressive stress vs. strain curves for Rene' 41 alloy sheet, reduced to "A" basis. Transverse direction only.



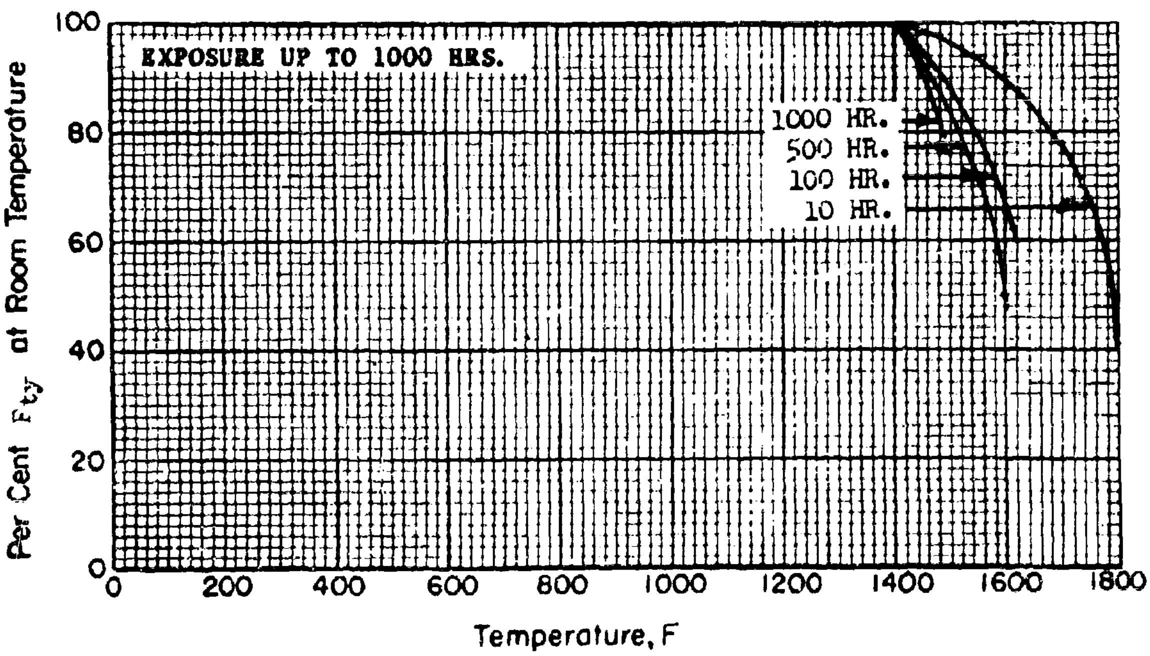
Effects of exposure temperature on elevated temperature ultimate tensile strength (F_{tu}) of Rene' 41 alloy foil, transverse direction. Exposure up to 1000-hours.



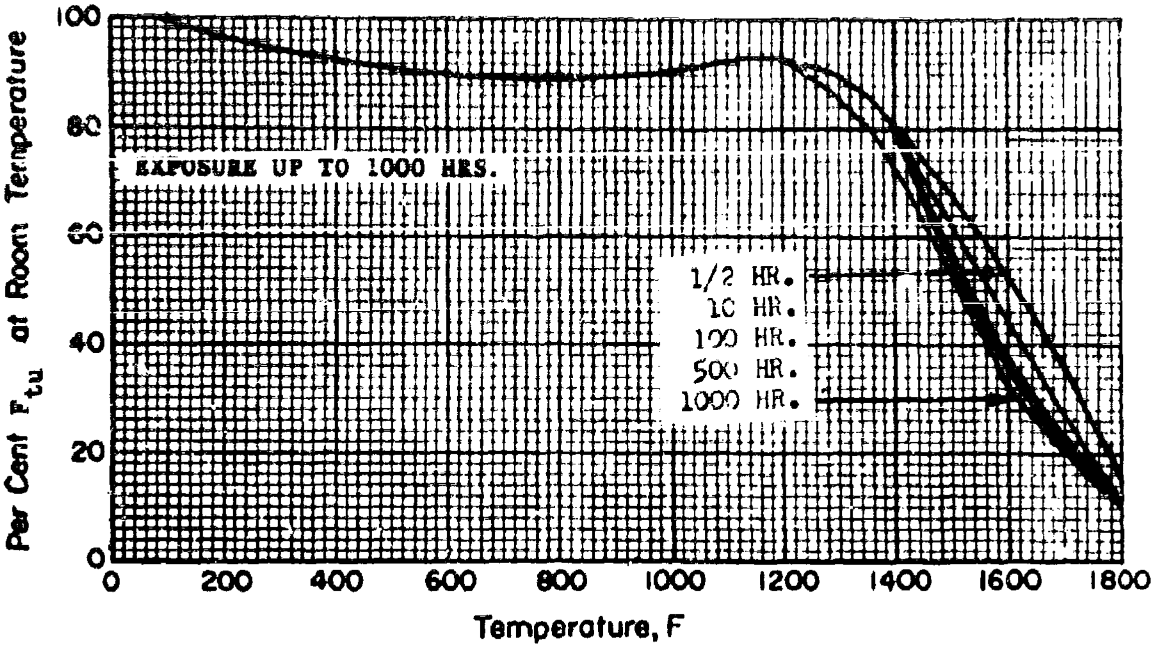
Effects of exposure temperature on elevated temperature tensile yield strength (F_{ty}) of Rene' 41 alloy foil, transverse direction. Exposure up to 1000-hours.



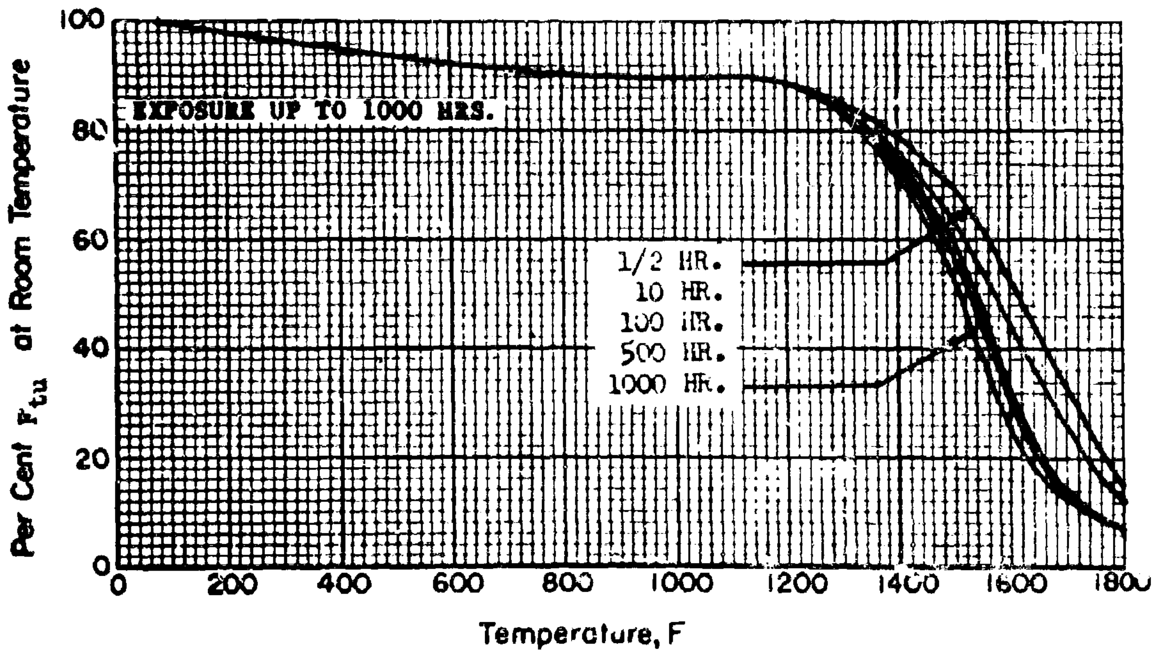
Effect of exposure temperature on room temperature ultimate tensile strength (F_{tu}) of Rene' 41 alloy foil, transverse direction. Exposure up to 1000-hours.



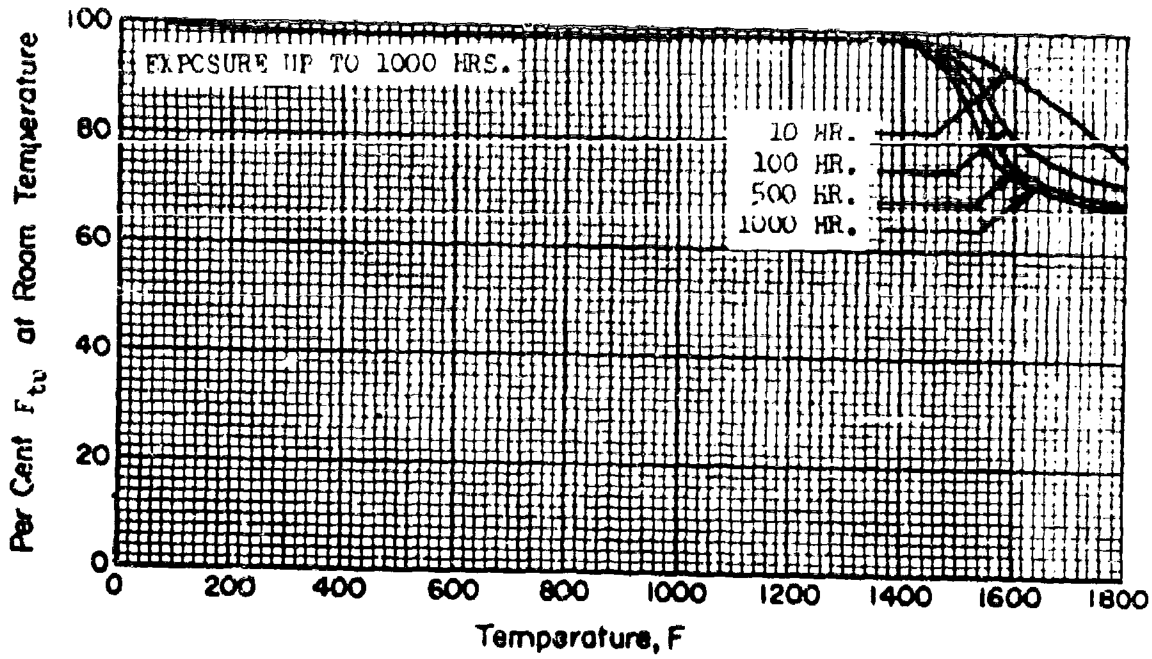
Effect of exposure temperature on room temperature tensile yield strength (F_{ty}) of Rene' 41 alloy foil, transverse direction. Exposure up to 1000-hours.



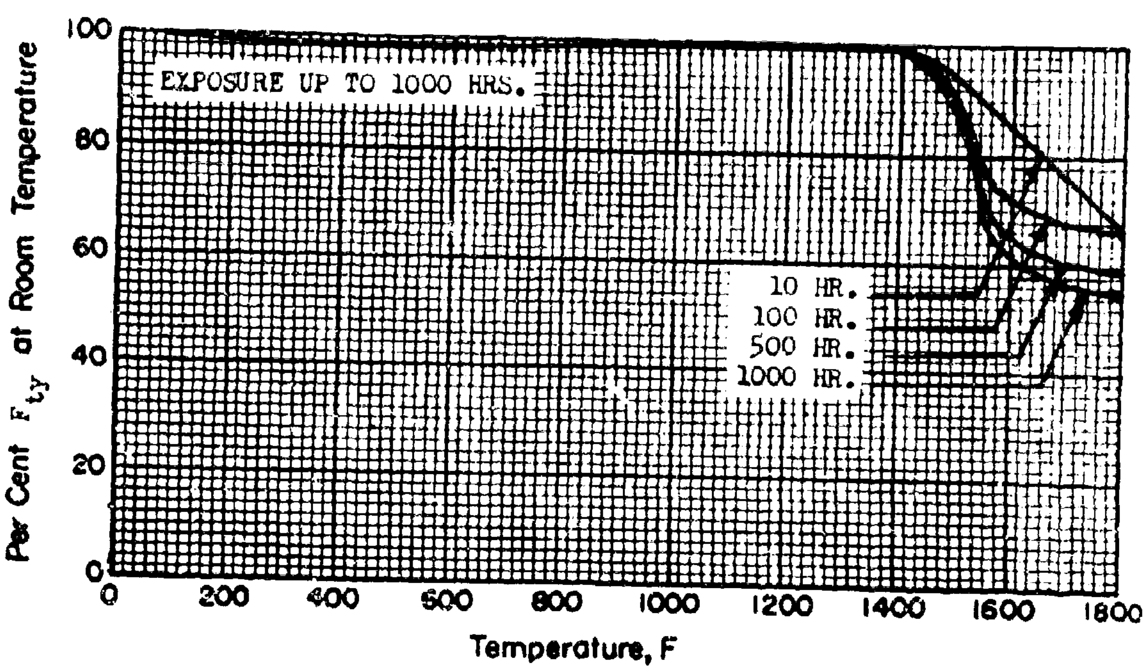
Effect of exposure temperature on elevated temperature ultimate tensile strength (F_{tu}) of Rene' 41 alloy sheet, transverse direction. Exposure up to 1000-hours.



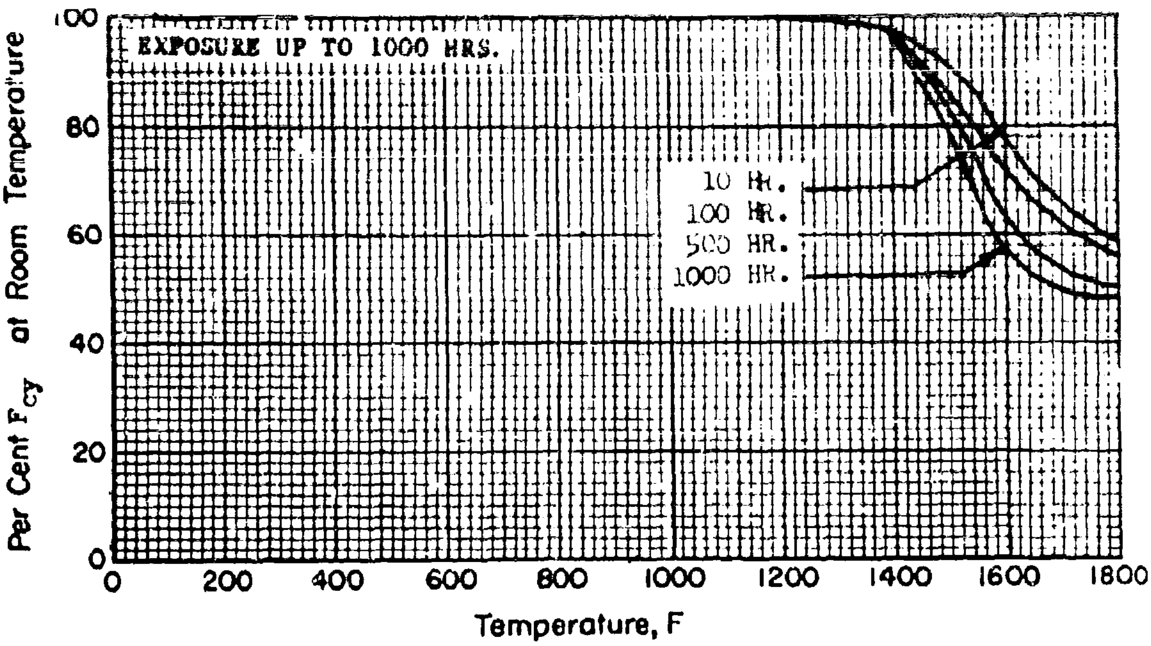
Effect of exposure temperature on elevated temperature tensile yield strength (F_{ty}) of Rene' 41 alloy sheet, transverse direction. Exposure up to 1000-hours.



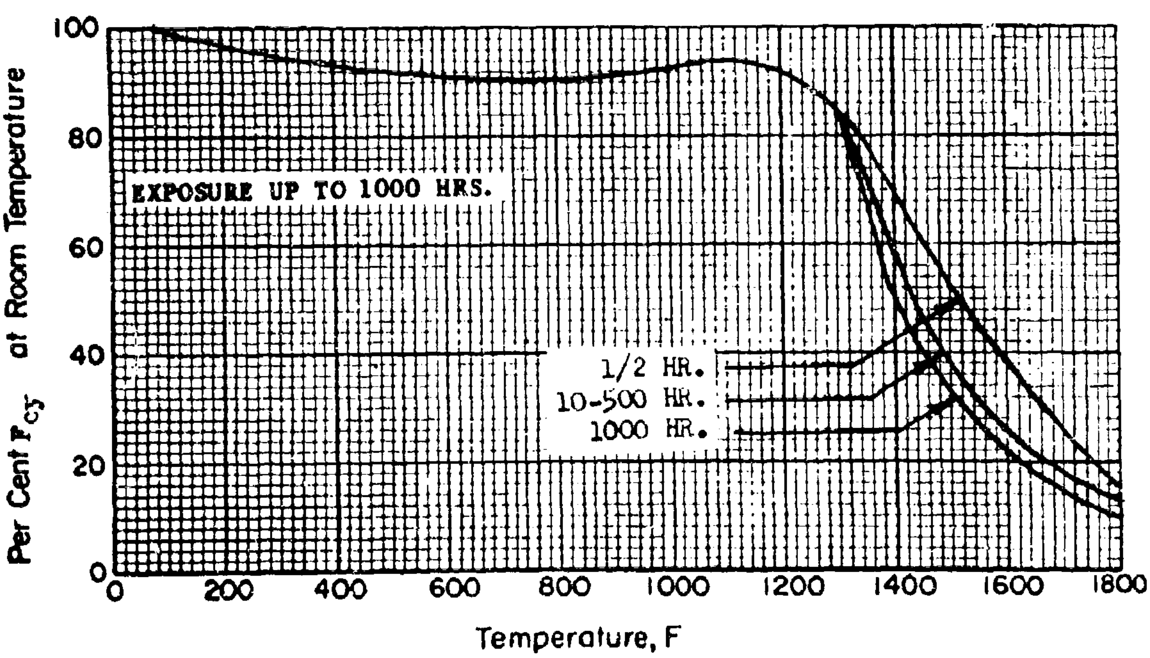
Effects of exposure to temperature on room temperature ultimate tensile strength (F_{tu}) of Rene' 41 alloy sheet, transverse direction. Exposure up to 1000-hours.



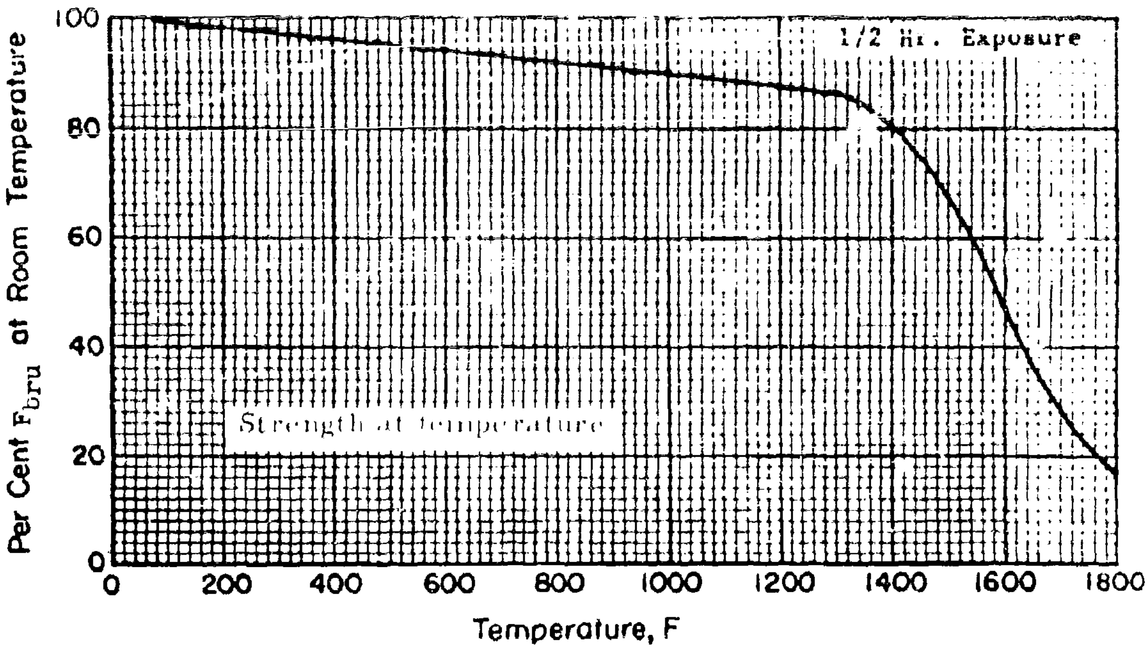
Effects of exposure temperature on room temperature tensile yield strength (F_{ty}) of Rene' 41 alloy sheet, transverse direction. Exposure up to 1000-hours.



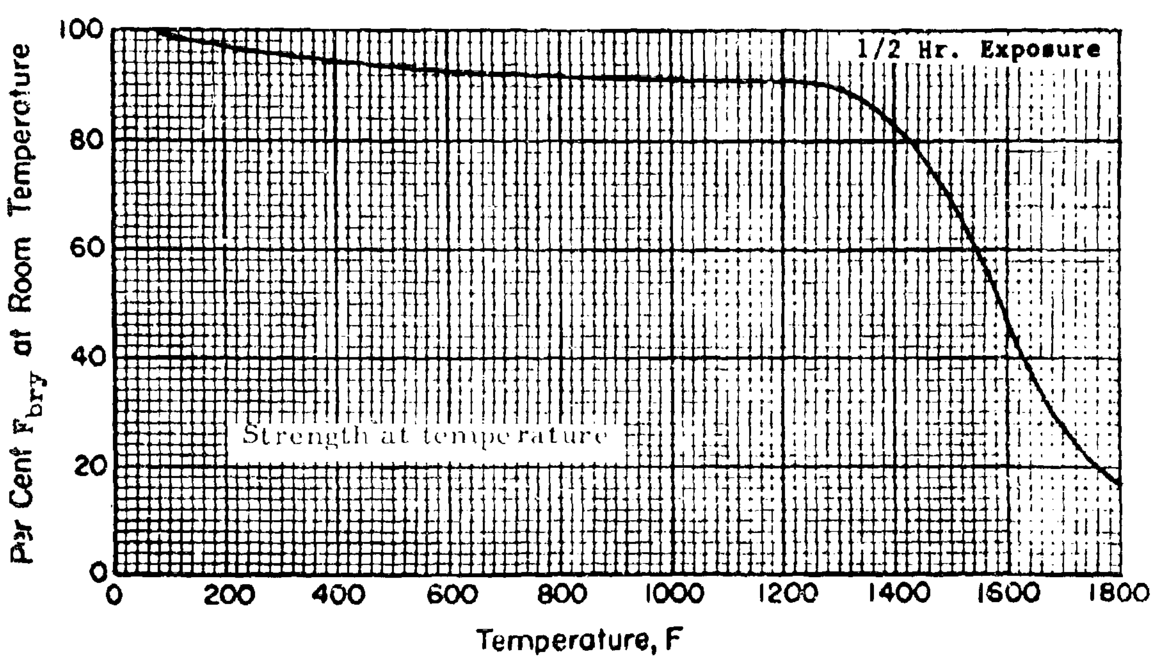
Effect of exposure temperature on room temperature compression yield strength (F_{cy}) of Rene' 41 alloy sheet, transverse direction. Exposure up to 1000-hours.



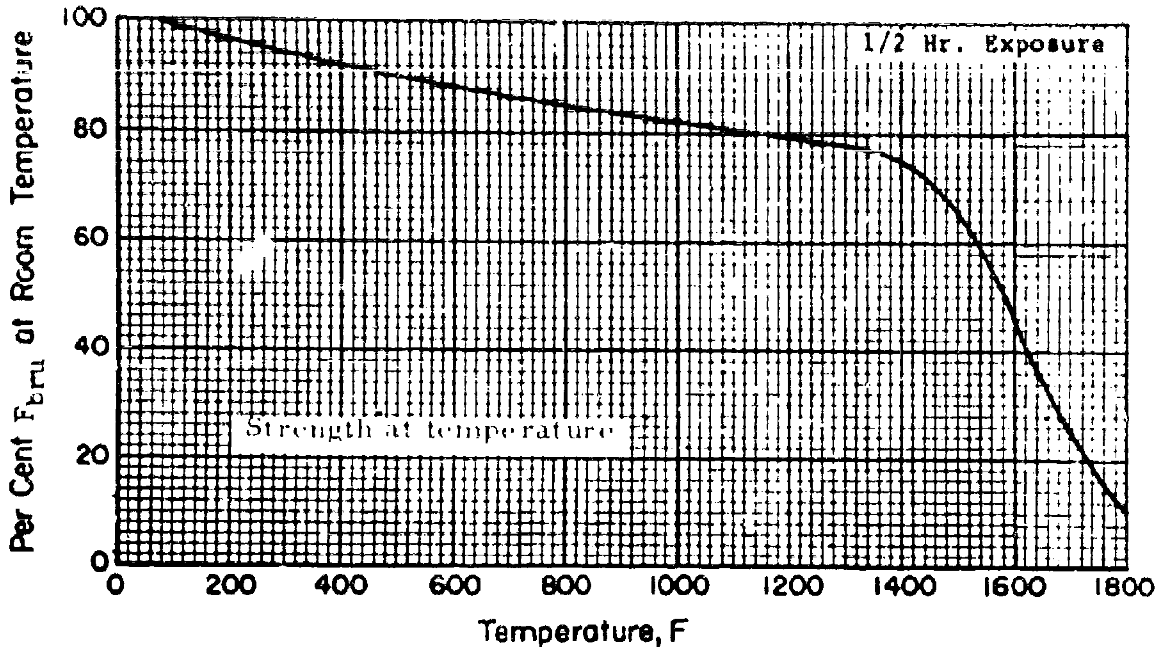
Effect of exposure temperature on elevated temperature compression yield strength (F_{cy}) of Rene' 41 alloy sheet, transverse direction. Exposure up to 1000-hours.



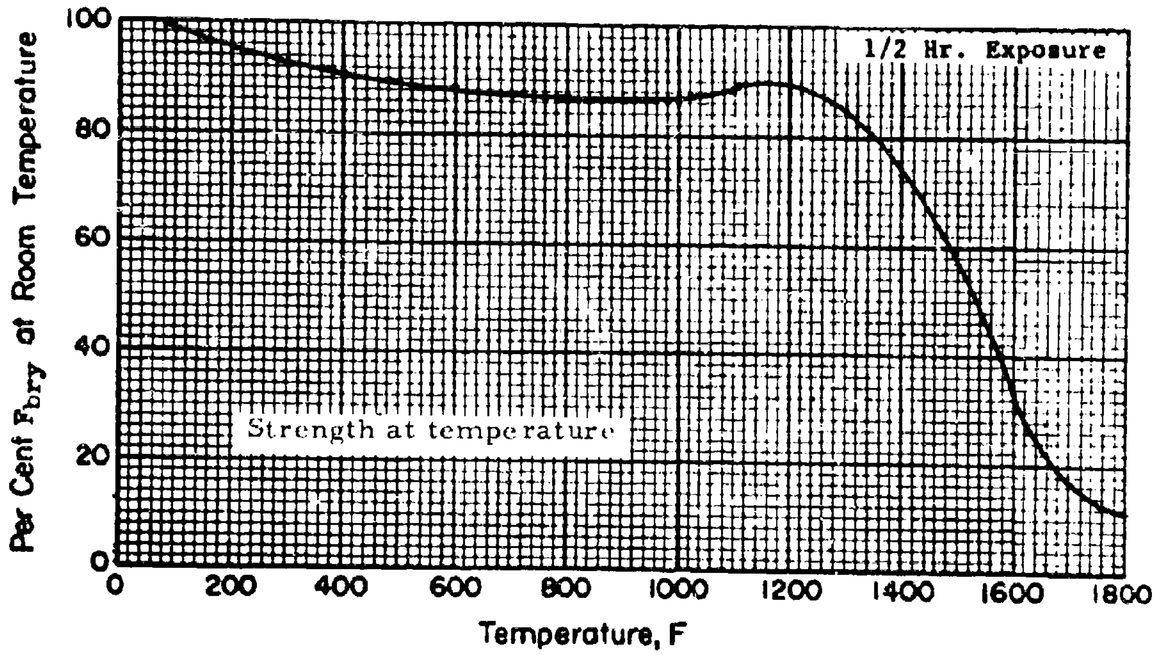
Effect of temperature on the ultimate bearing strength (F_{bru}) of Rene' 41 alloy sheet. Exposure up to 1/2-hour. e/D = 2.0. Longitudinal direction only.



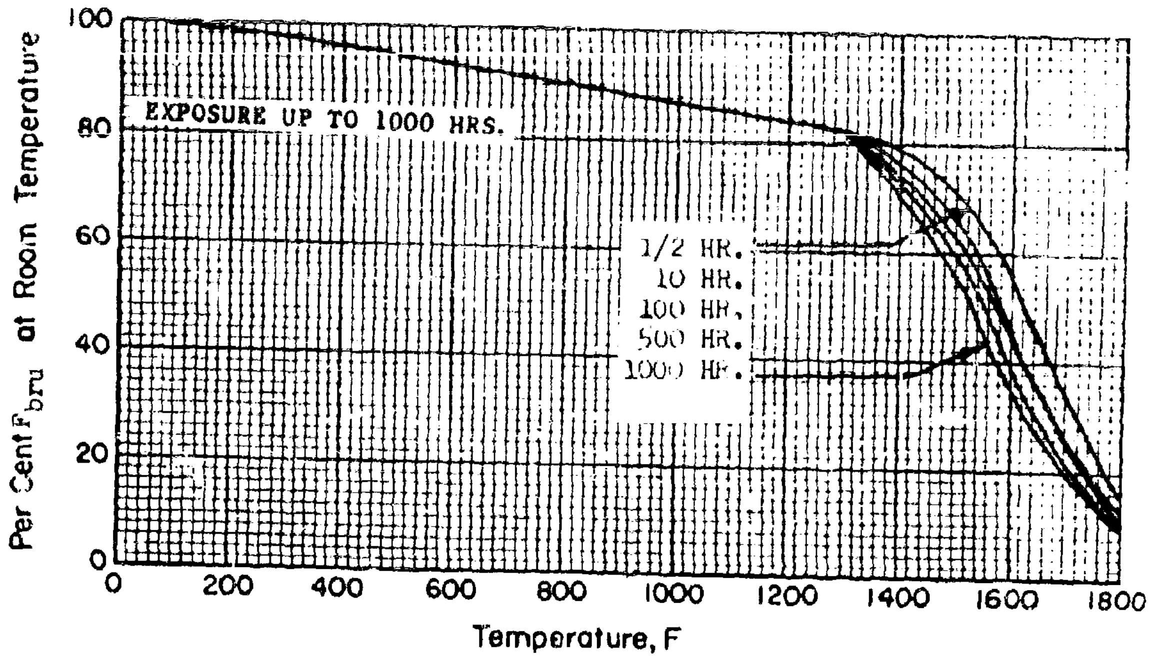
Effect of temperature on the bearing yield strength (F_{bry}) of Rene' 41 alloy sheet. Exposure up to 1/2-hour. e/D = 2.0. Longitudinal direction only.



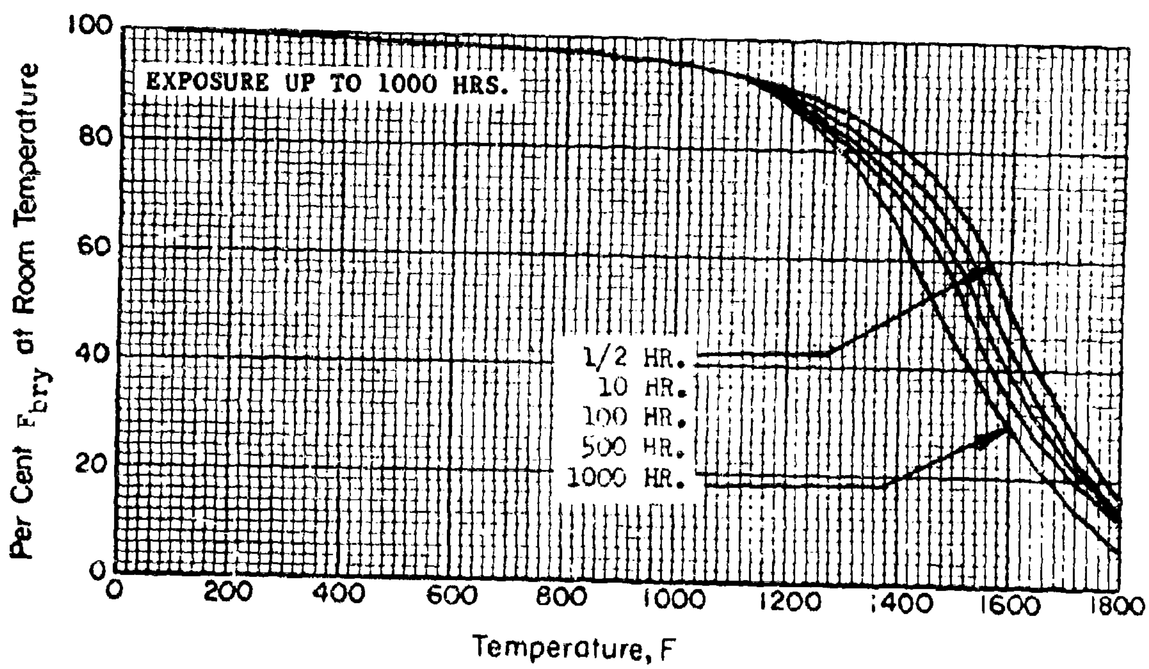
Effect of temperature on the ultimate bearing strength (F_{bru}) of Rene' 41 alloy sheet. Exposure up to 1/2-hour. e/D = 2.0. Transverse direction only.



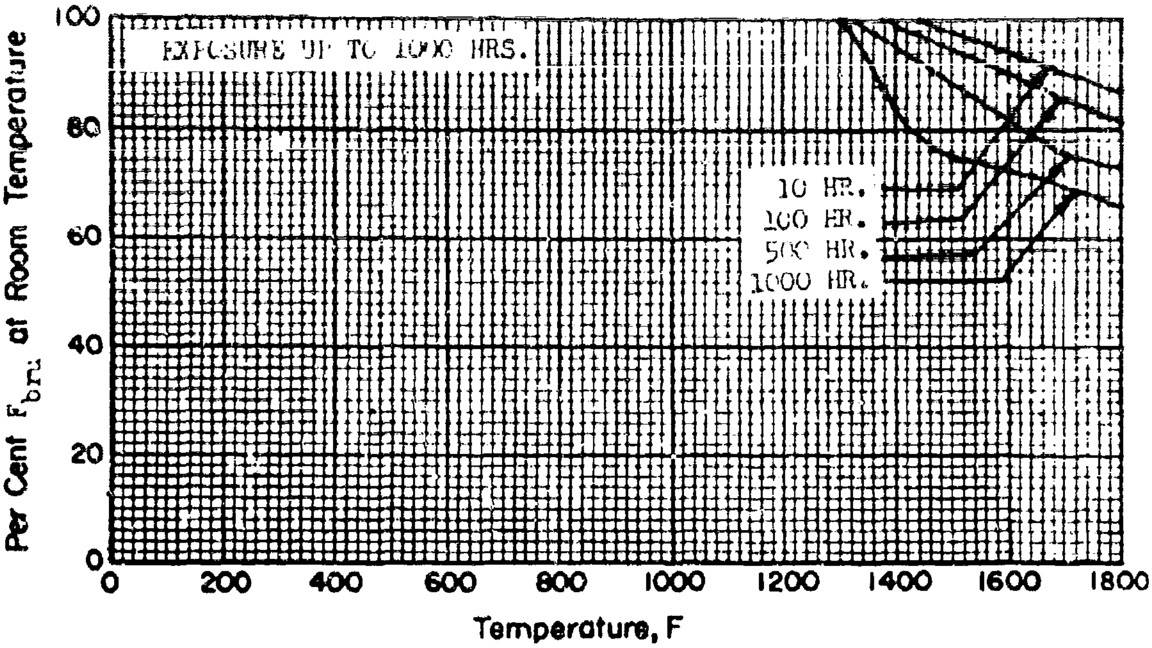
Effect of temperature on the bearing yield strength (F_{bry}) of Rene' 41 alloy sheet. Exposure up to 1/2-hour. e/D = 2.0. Transverse direction only.



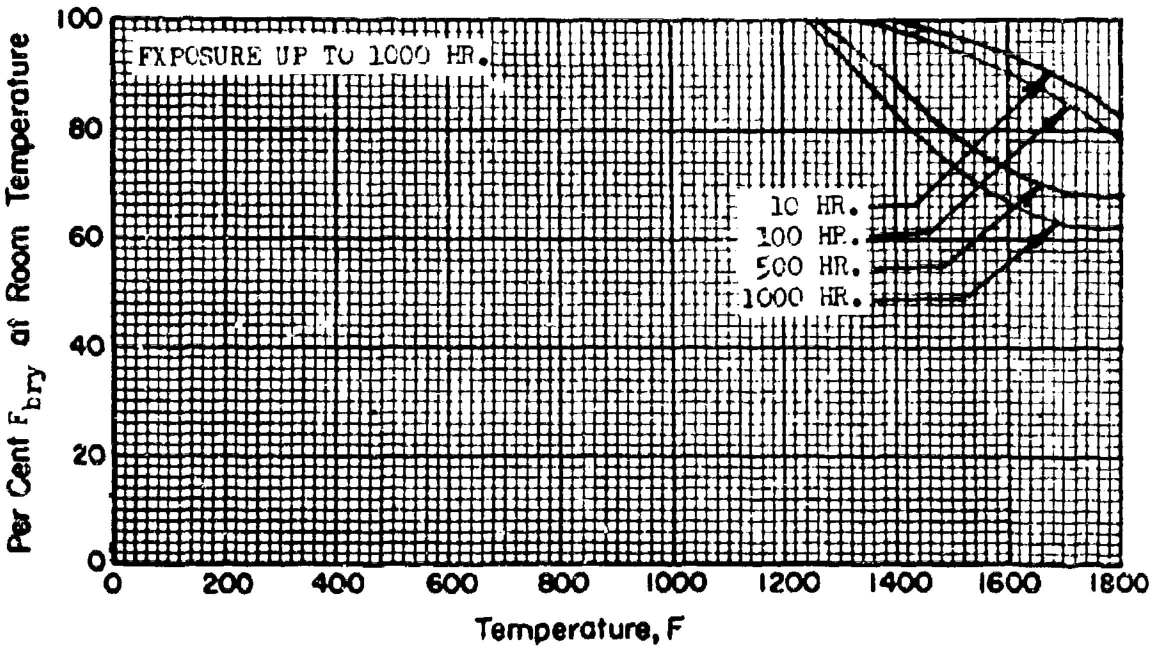
Effect of exposure temperature on elevated temperature bearing ultimate strength (F_{bru}) of Rene' 41 alloy sheet, transverse direction, for e/D = 1.5. Exposure up to 1000-hours.



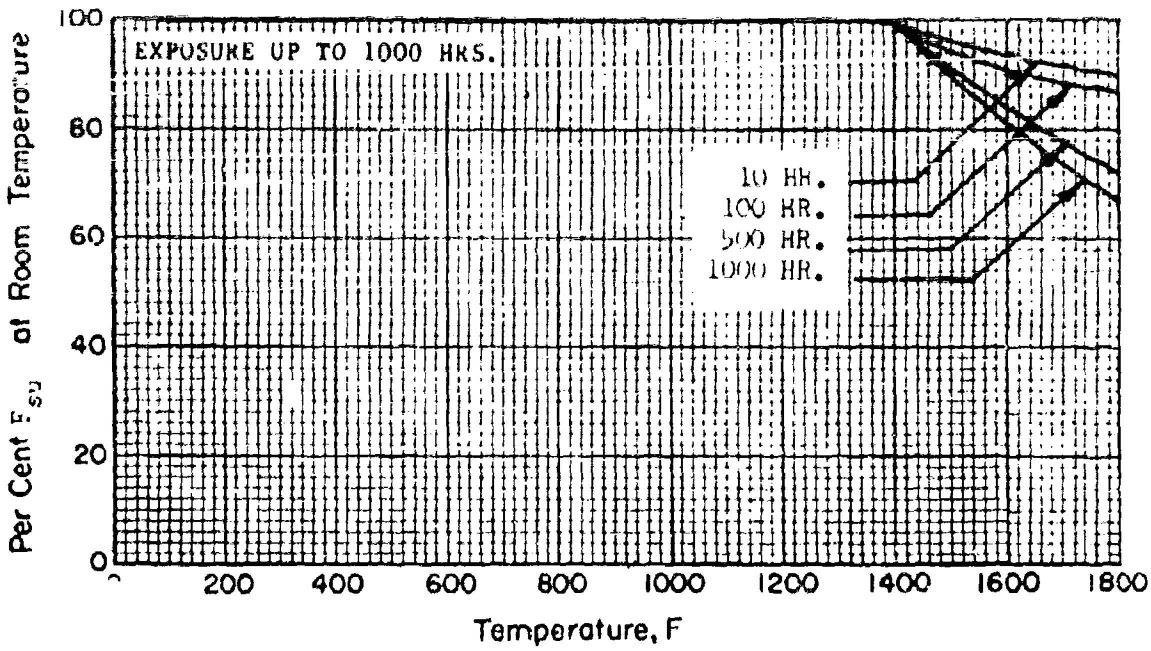
Effect of exposure temperature on elevated temperature bearing yield strength (F_{bry}) of Rene' 41 alloy sheet, transverse direction, e/D = 1.5. Exposure up to 1000-hours.



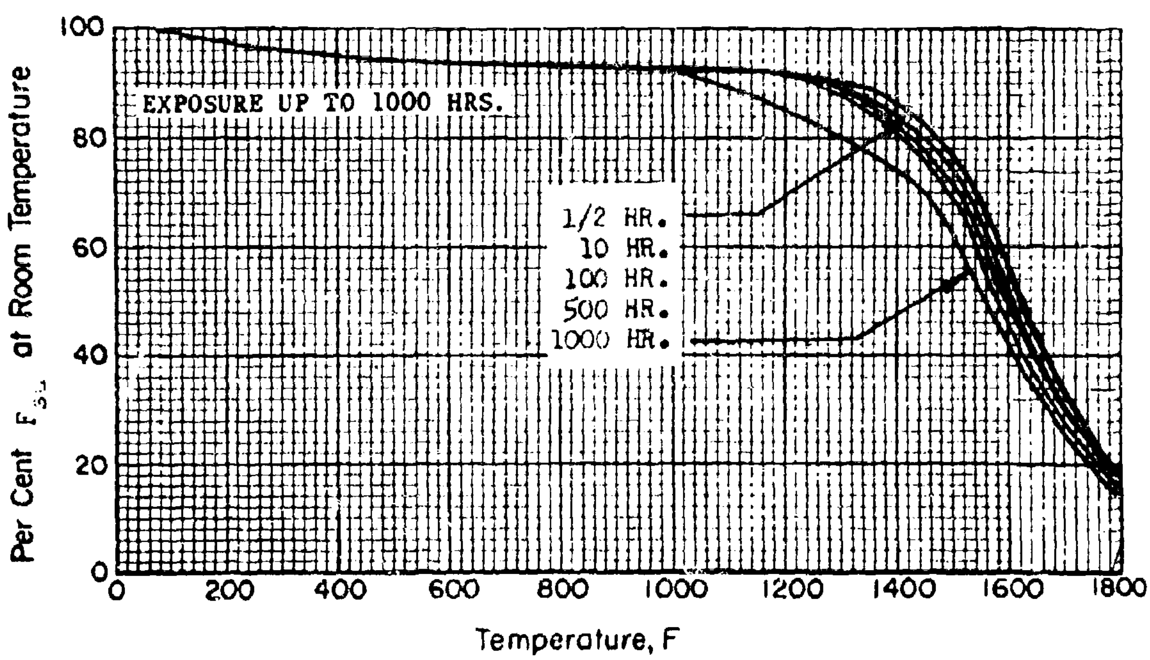
Effect of exposure temperature on room temperature bearing ultimate strength (F_{bru}) of Rene' 41 alloy sheet, transverse direction, for e/D = 1.5. Exposure up to 1000-hours.



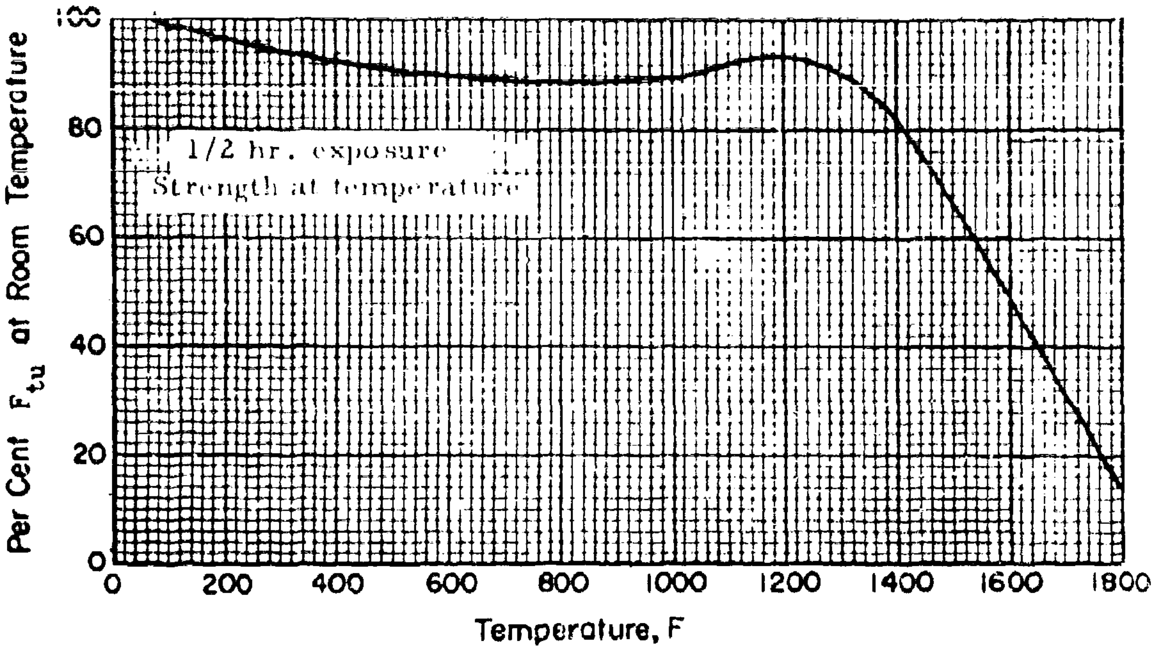
Effect of exposure temperature on room temperature bearing yield strength (F_{bry}) of Rene' 41 alloy sheet, transverse direction, for e/D = 1.5. Exposure up to 1000-hours.



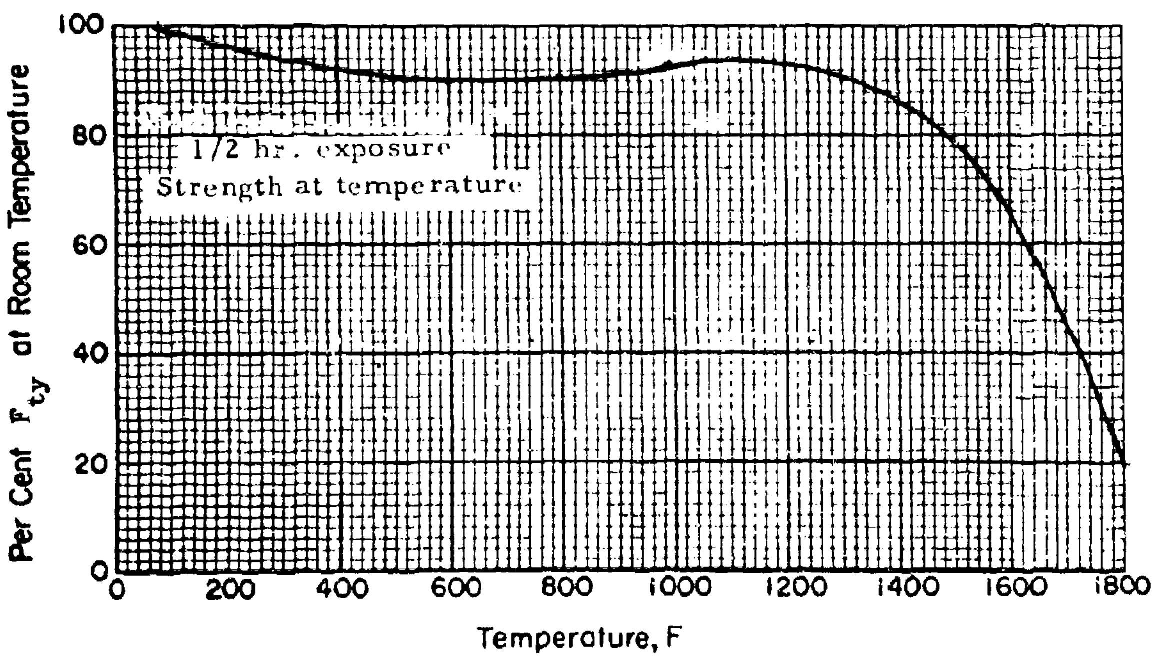
Effect of exposure temperature on room temperature shear ultimate strength (F_{su}) of Rene' 41 alloy sheet transverse direction. Exposure up to 1000-hours.



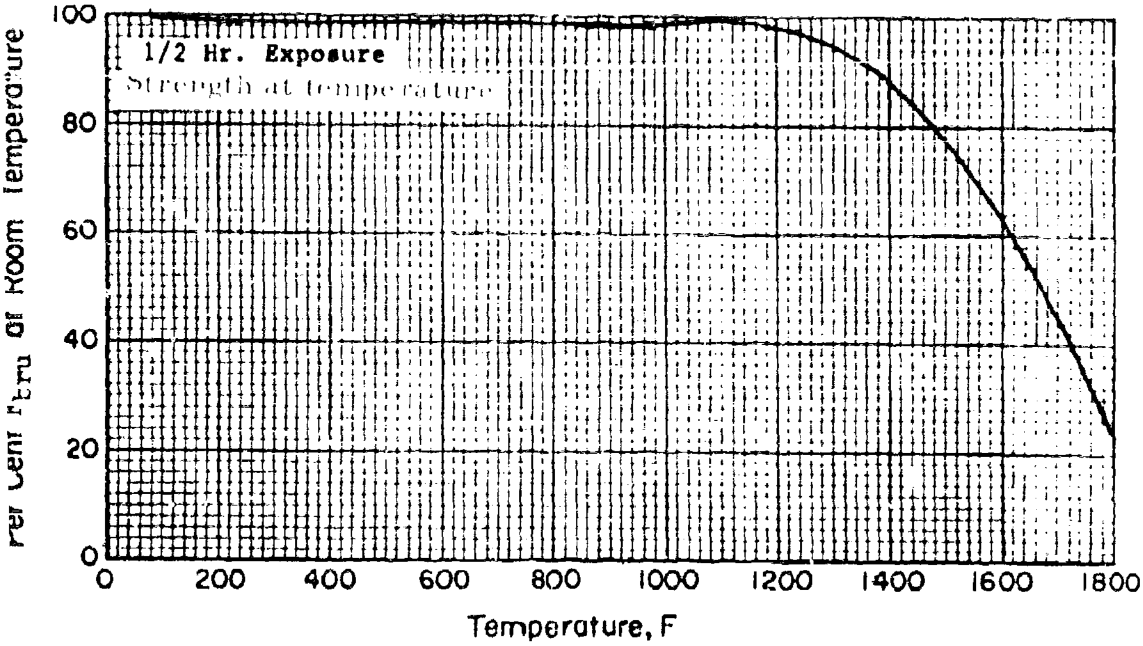
Effect of exposure temperature on elevated temperature shear ultimate strength (F_{su}) of Rene' 41 alloy sheet, transverse direction. Exposure up to 1000-hours.



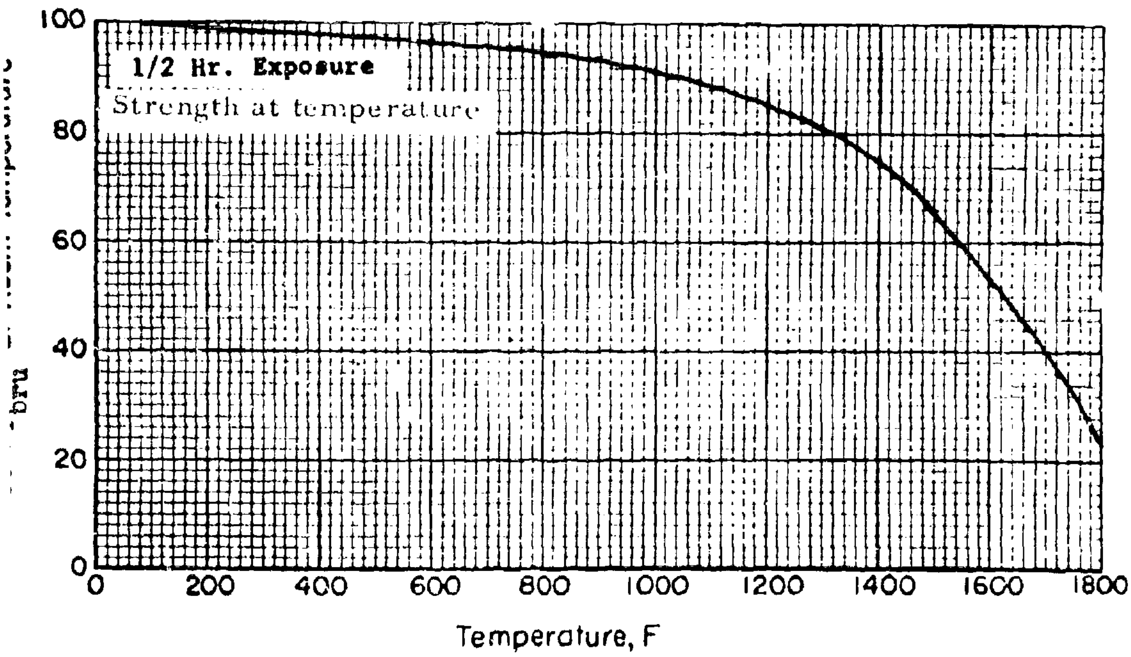
Effects of temperature on ultimate tensile strength (F_{tu}) of Rene' 41 alloy, bar, plate and forging; transverse and longitudinal directions.



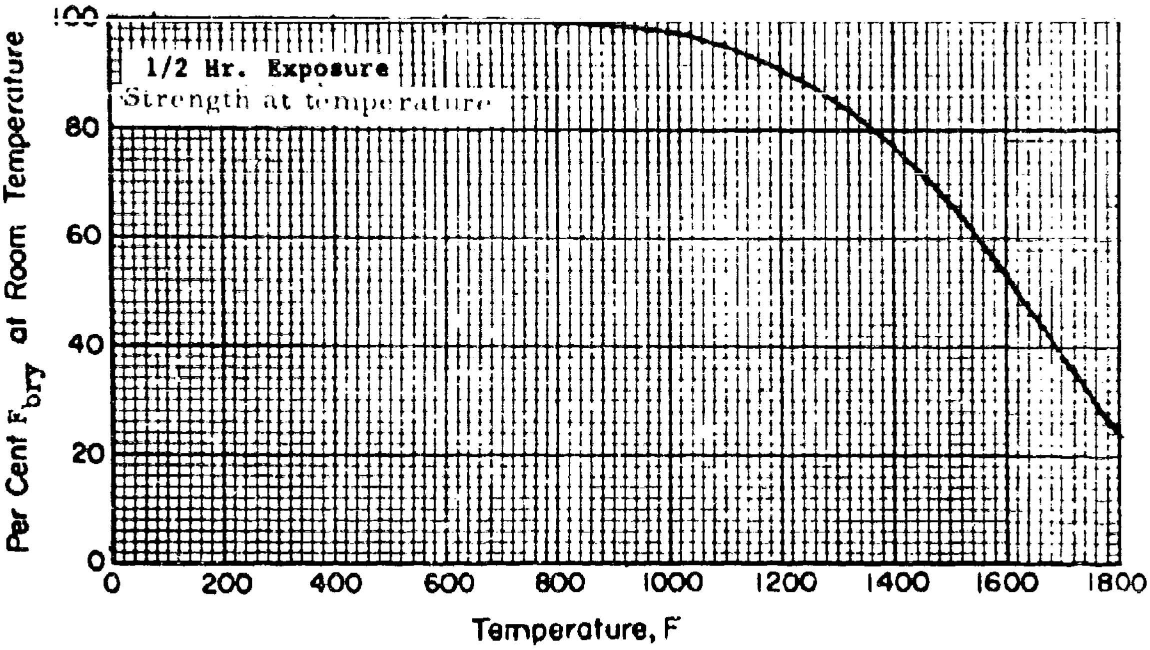
Effects of temperature on tensile yield strength (F_{ty}) of Rene' 41 alloy bar, plate and forging; transverse and longitudinal directions.



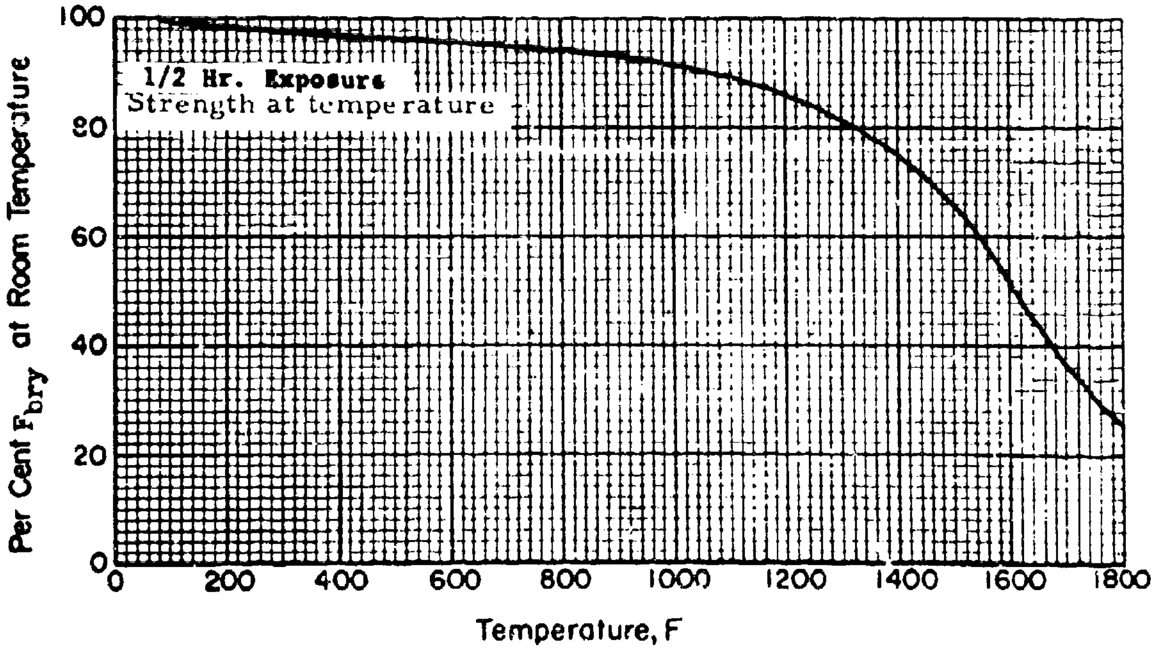
Effect of temperature on the bearing ultimate strength (F_{bru}) of Rene' 41 alloy plate, transverse and longitudinal directions, e/D = 1.5. Exposure up to 1/2-hour.



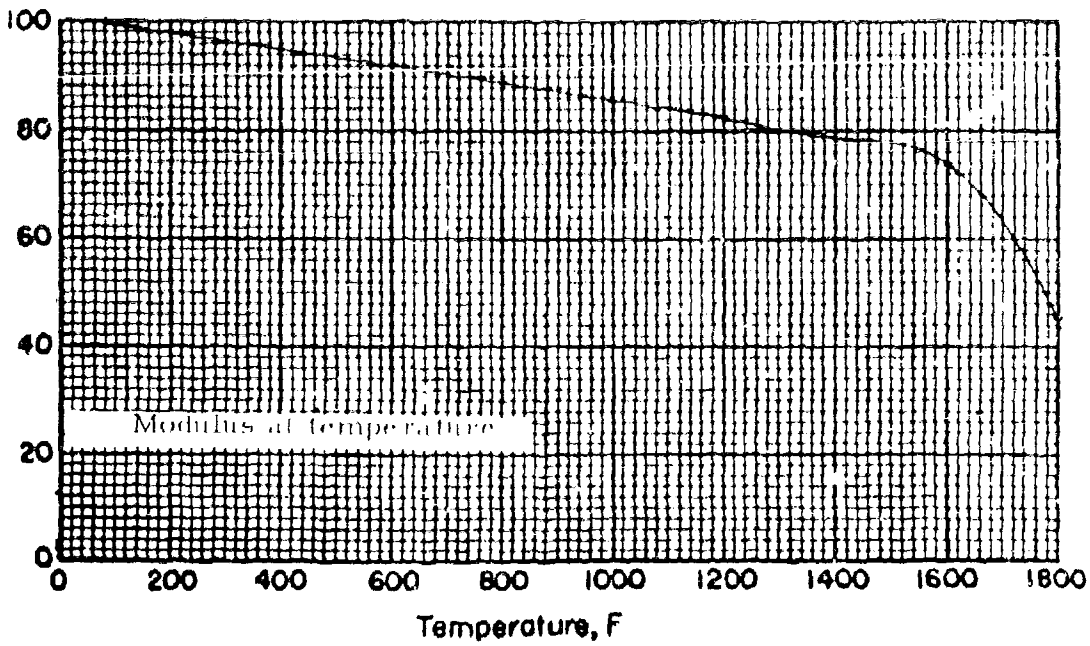
Effect of temperature on the bearing ultimate strength (F_{bru}) of Rene' 41 alloy plate, transverse and longitudinal directions, e/D = 2.0. Exposure up to 1/2-hour.



Effect of temperature on the bearing yield strength (F_{bry}) of Rene' 41 alloy plate, transverse and longitudinal directions, e/D = 1.5. Exposure up to 1/2-hour.



Effect of temperature on the bearing yield strength (F_{bry}) of Rene' 41 alloy plate, transverse and longitudinal directions, e/D = 2.0. Exposure up to 1/2-hour.



The effect of temperature on the elastic moduli, E and Ec, of Rene' 41 alloy.

SECTION VIII - MIL-HDBK-5 DATA PRESENTATION

8.2 MATERIAL, L-605

TABLE **DESIGN MECHANICAL AND PHYSICAL PROPERTIES OF**

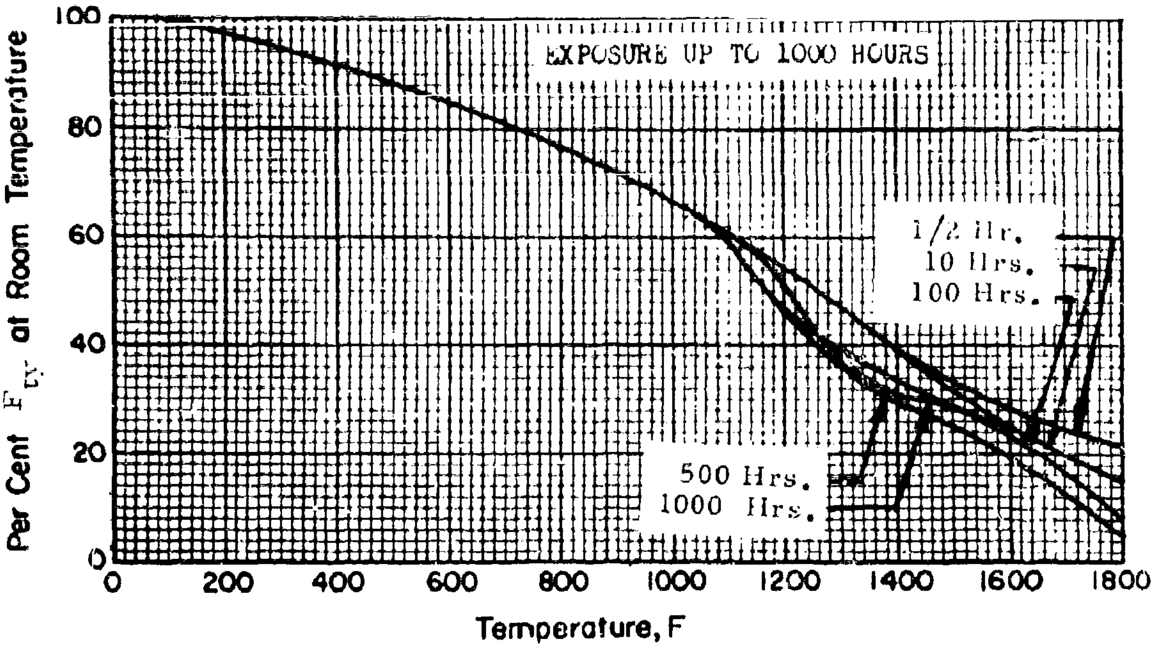
Alloy	L-605			
Form	Sheet (.020" $\leq$ t $\leq$ .187")			
Condition	Solution Treated			
DIRECTION	L		T	
Basis	A	B	A	B
Mechanical Properties				
F_{tu}, ksi	128.4	132.4	131.4	135.5
F_{ty}, ksi	62.8	66.3	60.9	64.3
F_{cy}, ksi	42.6	45.0	63.0	66.6
F_{su}, ksi	108.9	112.3	112.0	115.4
F_{bru}, ksi				
(e/D = 1.5)	184.9	190.7	187.9	193.8
(e/D = 2.0)	229.7	236.9	226.3	233.3
F_{bry}, ksi				
(e/D = 1.5)	93.6	98.8	102.9	108.7
(e/D = 2.0)	118.2	124.8	122.2	129.0
e, per cent				
E, 10^6 psi	32.9		32.9	
E_c, 10^6 psi	30.8		30.8	
G, 10^6 psi				
Physical Properties				
ω, lb/in.^{3}				
C, Btu/(lb)(F)				
K, Btu/[(hr)(ft^2)(F)/ft]				
α, 10^{-6} in./in./F				

TABLE DESIGN MECHANICAL AND PHYSICAL PROPERTIES OF

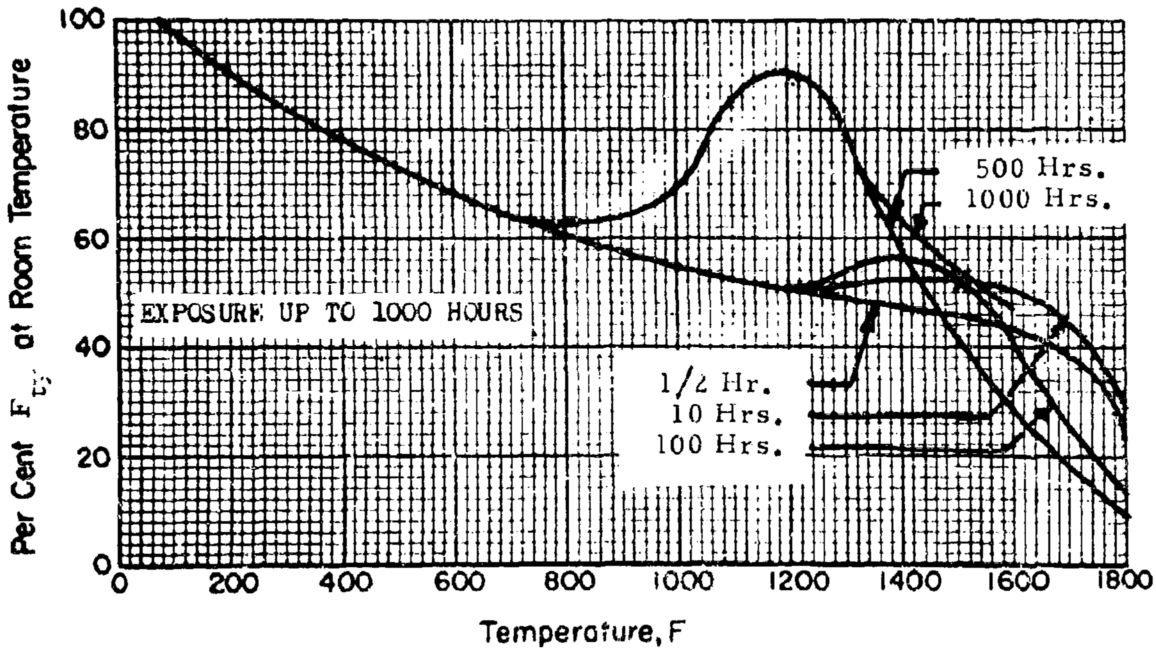
Alloy	L-605				
Form	Plate, Bar and Forging				
Condition	Solution Treated				
DIRECTION	L		T		
Basis	A	B	A	B	
Mechanical Properties					
F_{tu}, ksi	133.7	136.9	130.6	134.8	
F_{ty}, ksi	60.2	63.6	56.2	62.1	
F_{cy}, ksi	58.3	61.6	53.7	59.3	
F_{su}, ksi	98.1	100.5	95.9*	98.9*	
F_{bru}, ksi					
(e/D = 1.5)		184.0	189.9		
(e/D = 2.0)					
F_{bry}, ksi					
(e/D = 1.5)			96.9	107.1	
(e/D = 2.0)					
e, per cent					
E, 10^6 psi	32.9		32.9		
E_c, 10^6 psi	30.8		30.8		
G, 10^6 psi					
Physical Properties					
ω, lb/in.^{3}					
C, Btu/(lb)(F)					
K, Btu/[(hr)(ft^2)(F)/ft]					
α, 10^{-6} in./in./F					

* Tentative for Bar

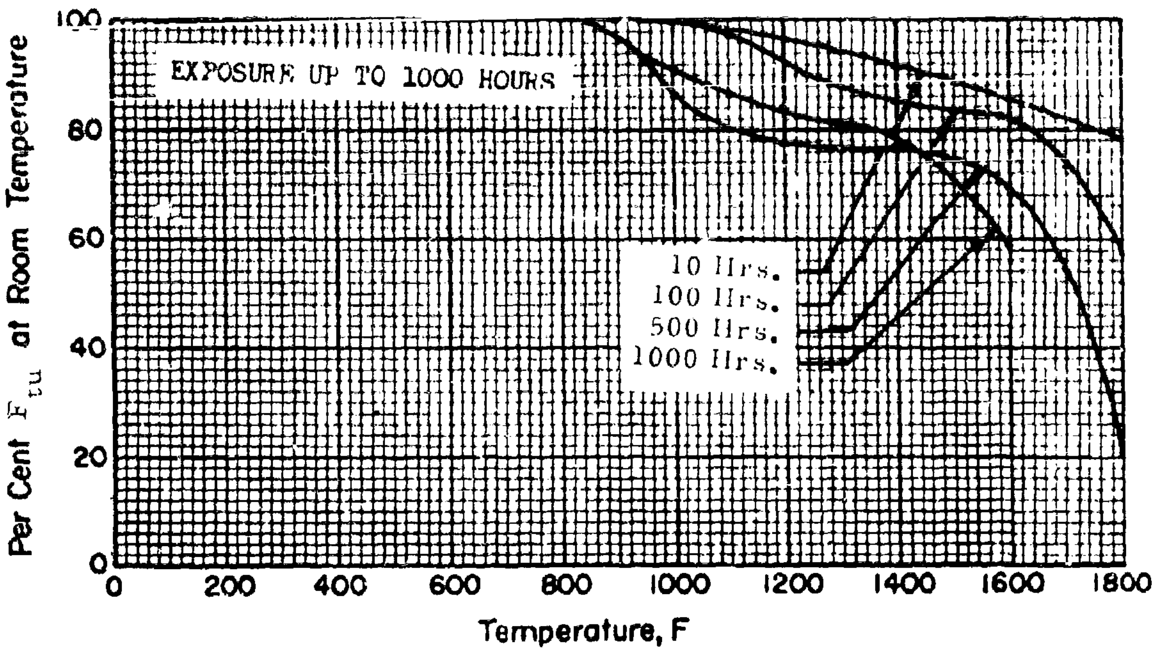
Page 469 has been eliminated data incorporated on Table, page 468.



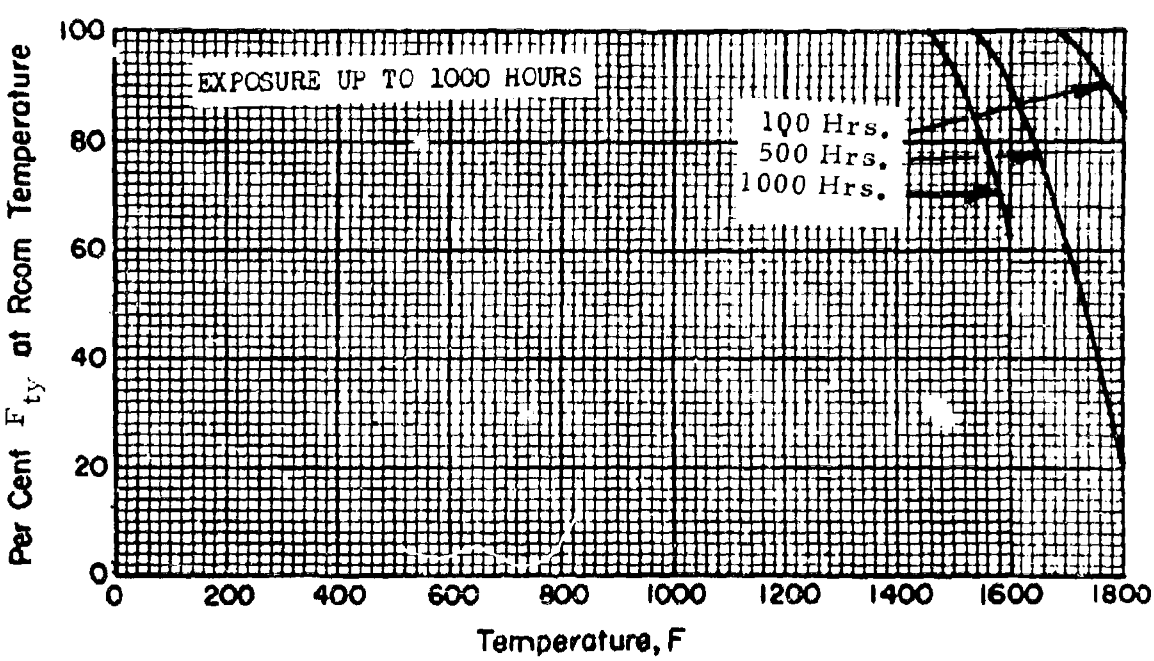
Effect of exposure time on the elevated temperature ultimate tensile strength (F_{tu}) of L-605 alloy foil. Exposure up to 1000-hours. Transverse direction only.



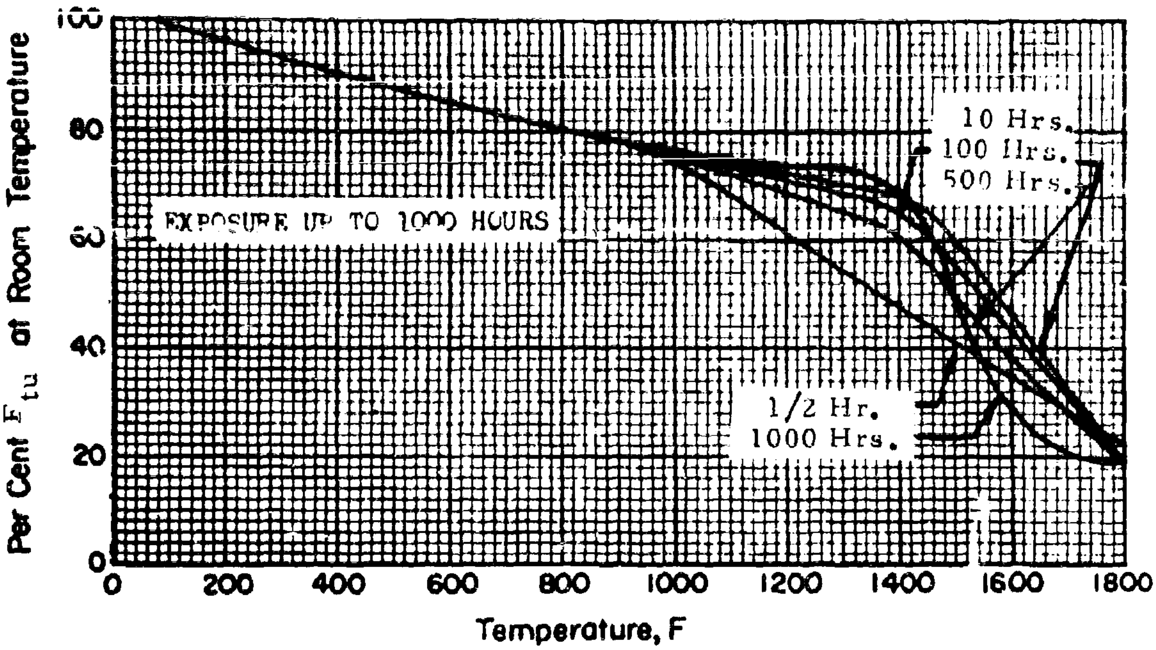
Effect of exposure time on the elevated temperature tensile yield strength (F_{ty}) of L-605 alloy foil. Exposure up to 1000 hours. Transverse direction only.



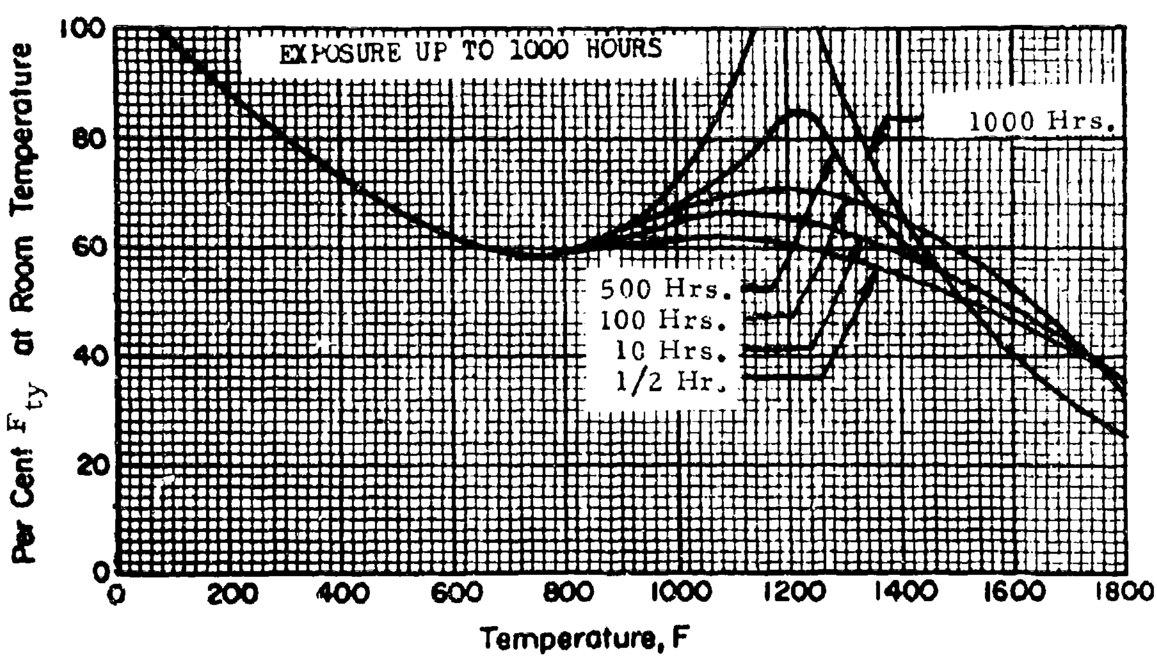
Effect of exposure at elevated temperature on the room temperature ultimate tensile strength (F_{tu}) of L-605 alloy foil. Exposure up to 1000-hours. Transverse direction only.



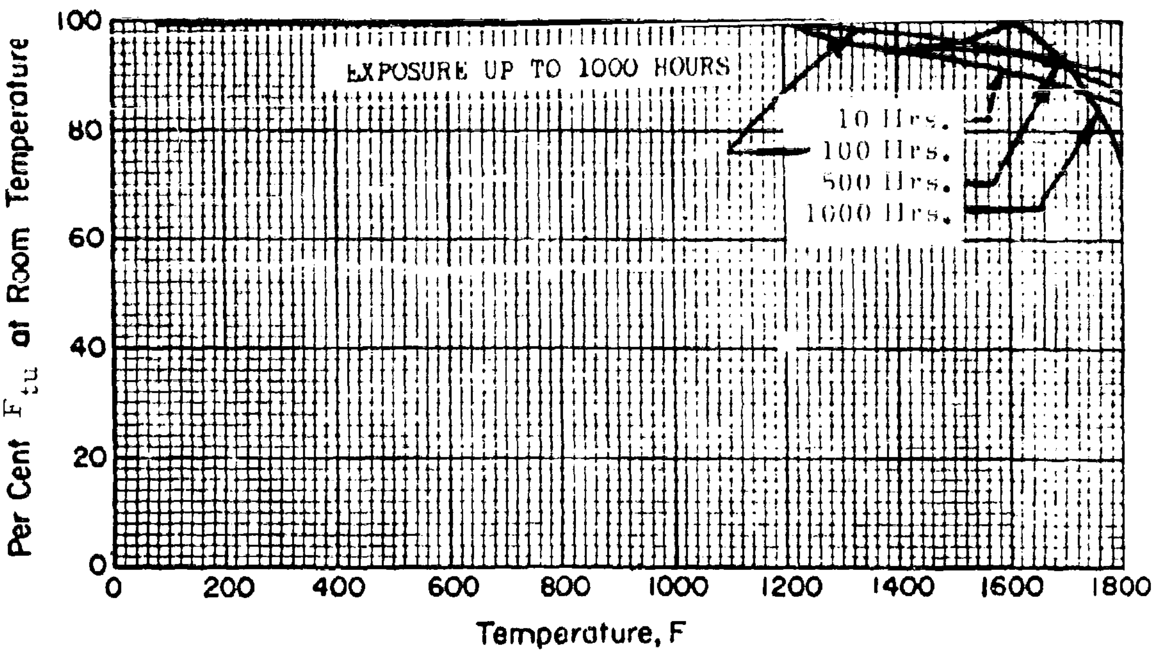
Effect of exposure at elevated temperature on the room temperature tensile yield strength (F_{ty}) of L-605 alloy foil. Exposure up to 1000-hours. Transverse direction only.



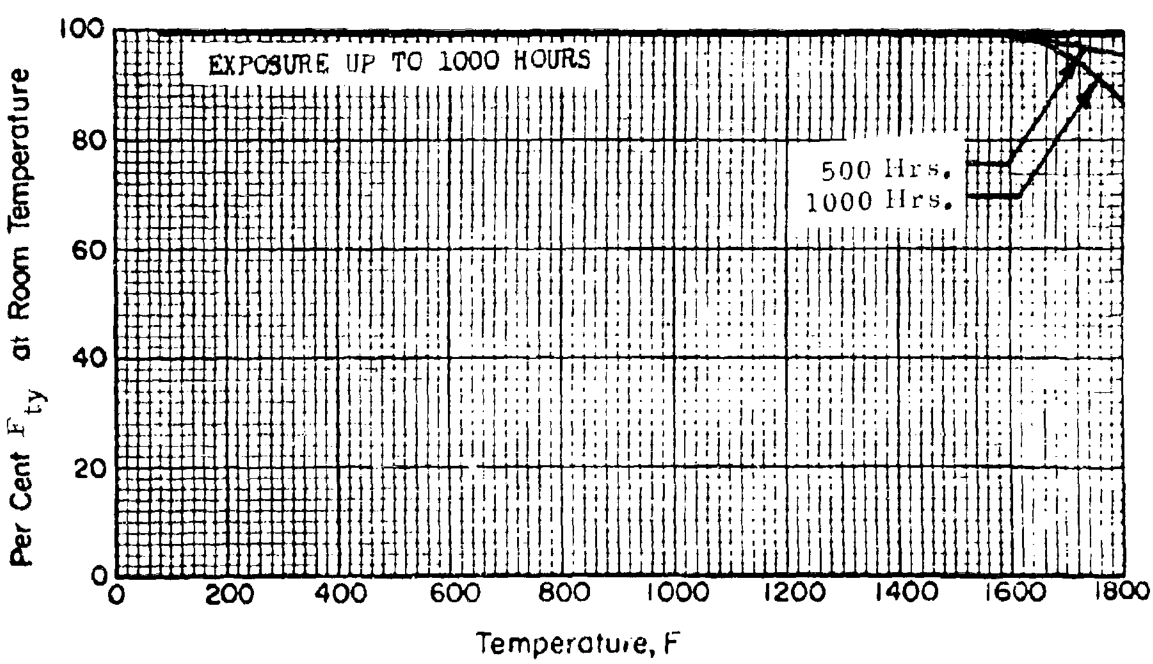
Effect of exposure time on the elevated temperature ultimate tensile strength (F_{tu}) of L-605 alloy sheet. Exposure up to 1000-hours.



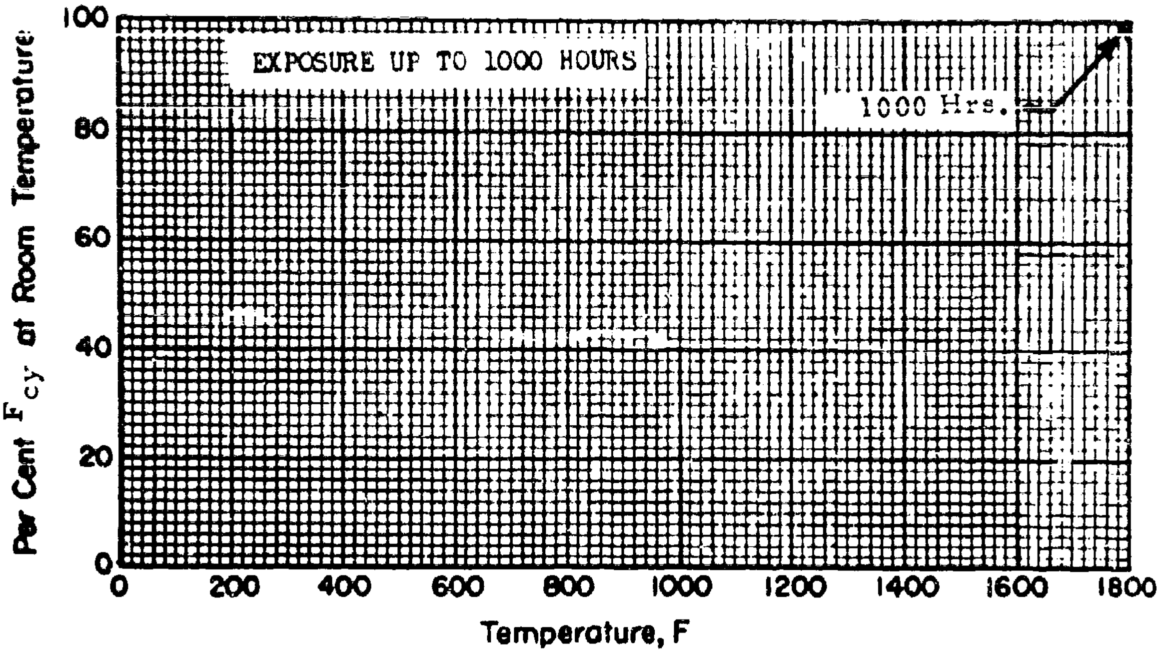
Effect of exposure time on the elevated temperature tensile yield strength (F_{ty}) of L-605 alloy sheet. Exposure up to 1000-hours.



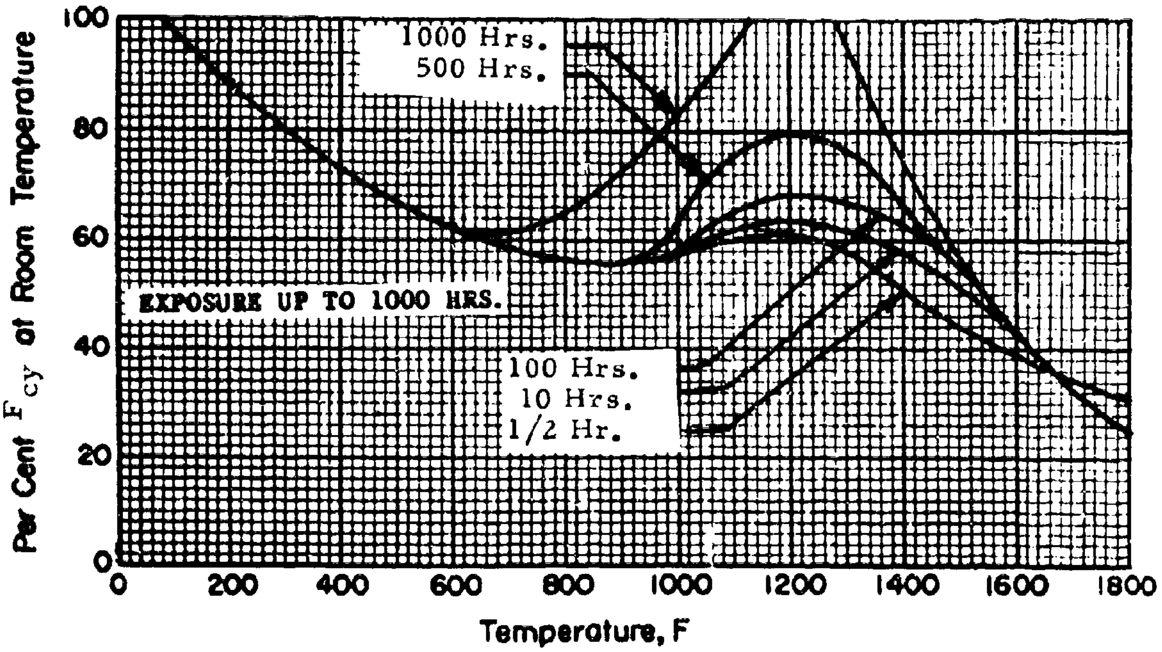
Effect of exposure at elevated temperature on the room temperature ultimate tensile strength (F_{tu}) of L-605 alloy sheet. Exposure up to 1C00-hours.Transverse direction only.



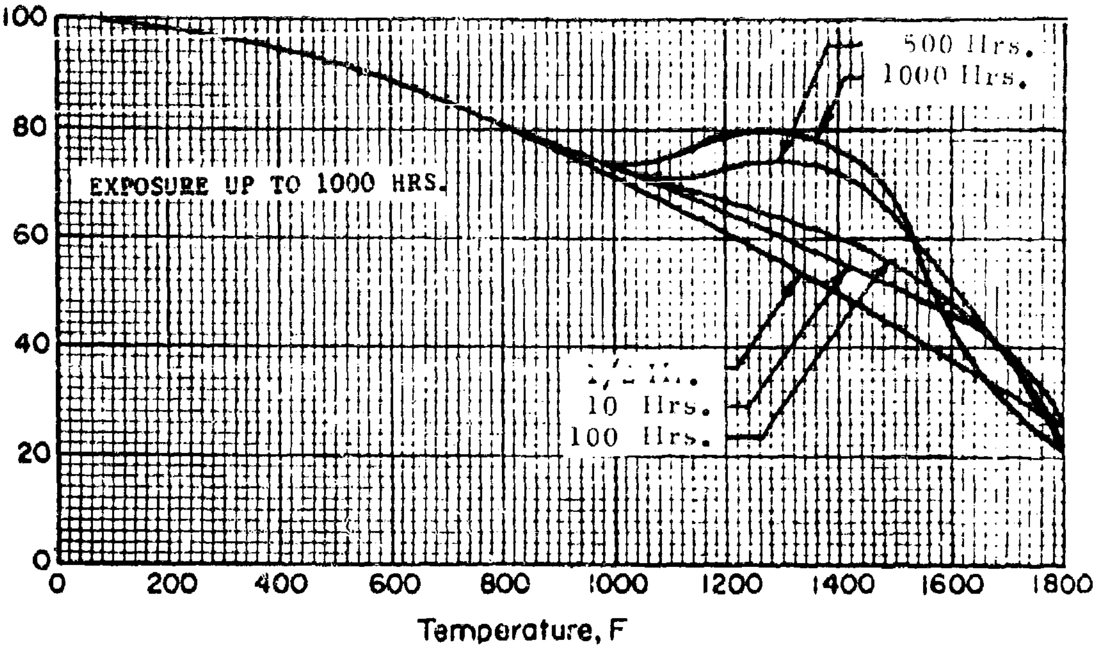
Effect of exposure at elevated temperature on the room temperature tensile yield strength (F_{ty}) of L-605 alloy sheet. Exposure up to 1000-hours. Transverse direction only.



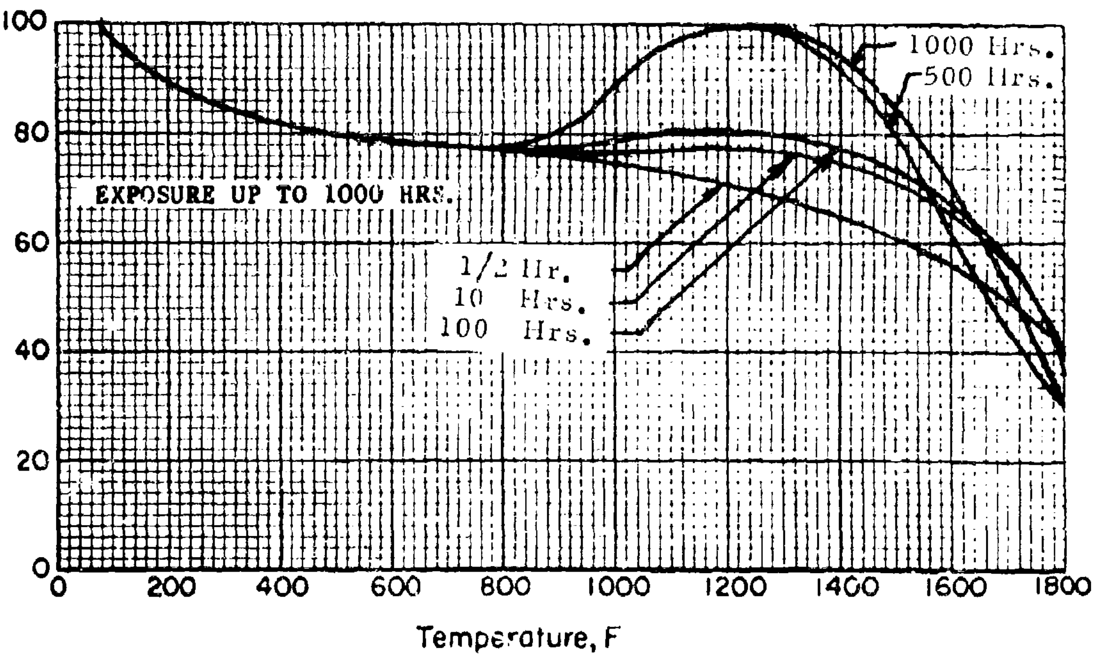
Effect of exposure at elevated temperature on the room temperature compressive yield strength (F_{cy}) of L-605 alloy sheet. Exposure up to 1000-hours. Transverse direction only.



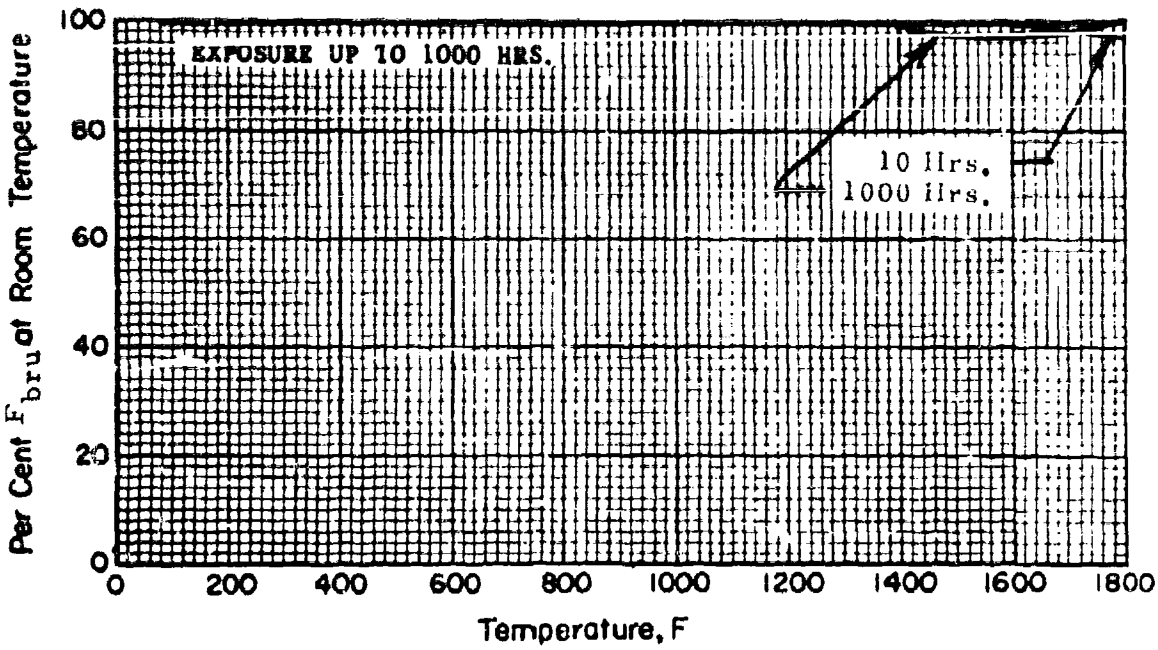
Effect of exposure time on elevated tempe ature compressive yield strength (F_{cy}) of L-605 alloy sheet. Exposure up to 1000-hours. Transverse direction only.



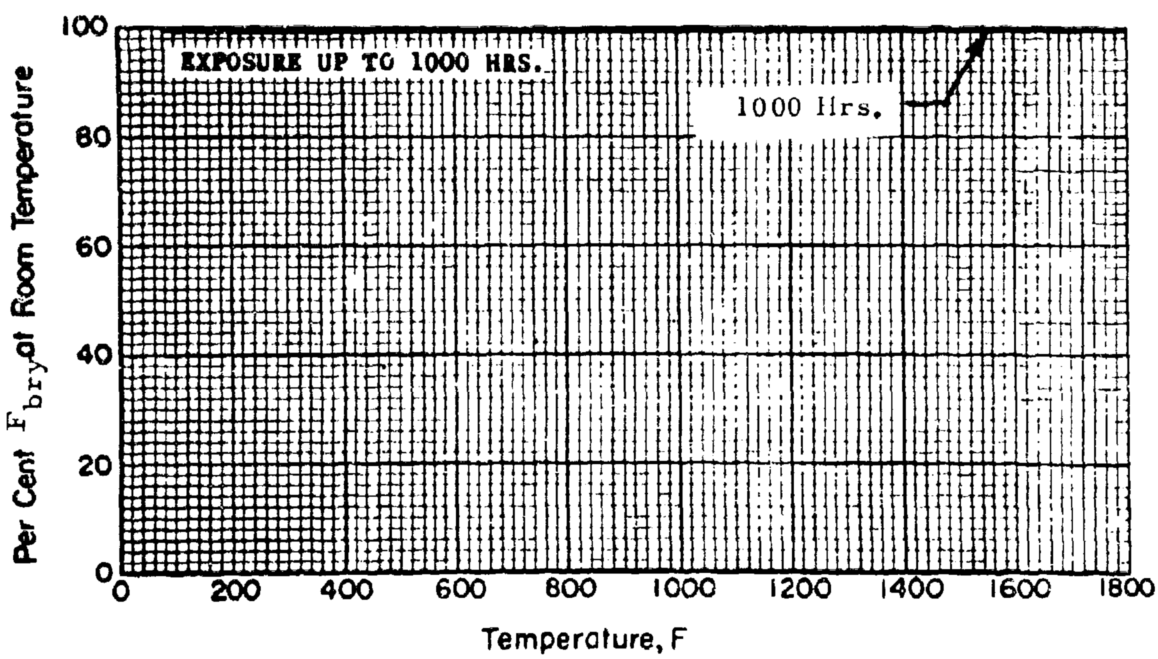
Effect of exposure time on the elevated temperature bearing ultimate strength (F_{bru}) of L-605 alloy sheet. Exposure up to 1000-hours. e/D = 1.5. Transverse direction only.



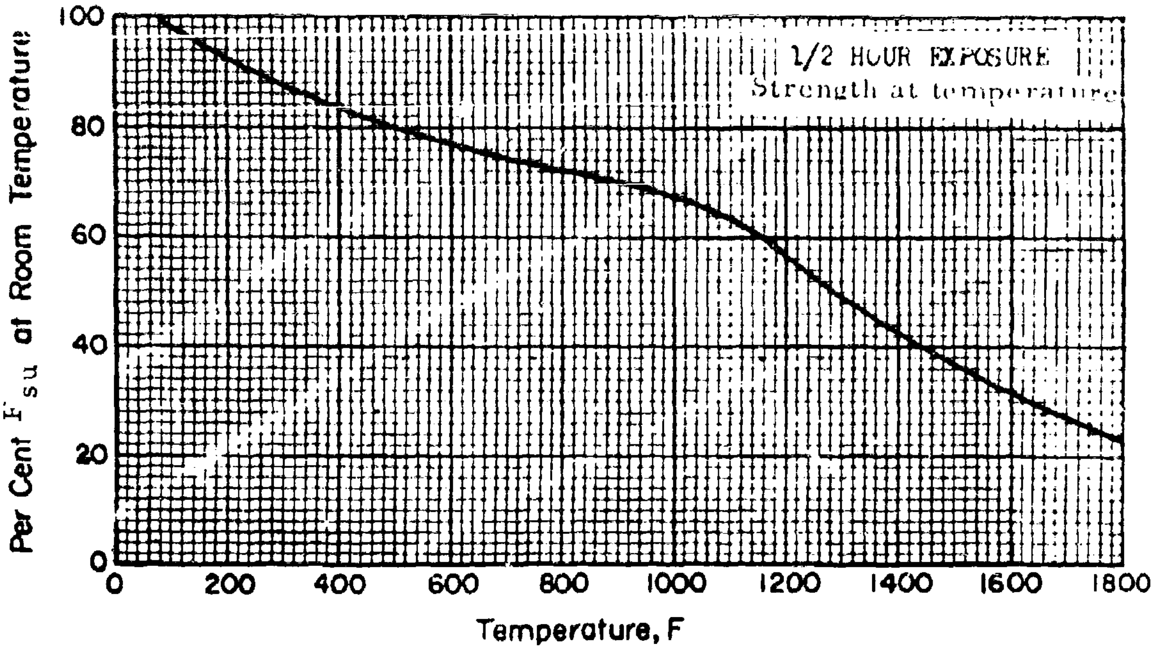
Effect of exposure time on the elevated temperature bearing yield strength (F_{bry}) of L-605 alloy sheet. Exposure up to 1000-hours. e/D = 1.5. Transverse direction only.



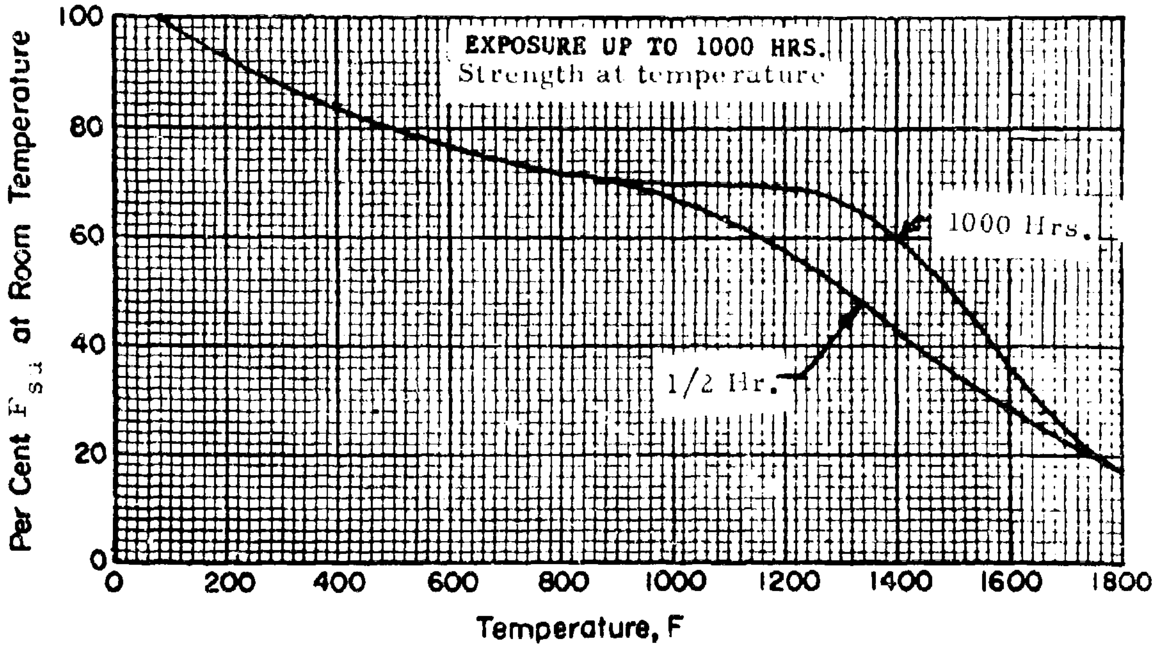
Effect of exposure at elevated temperature on the room temperature bearing ultimate strength (F_{bru}) of L-605 alloy sheet. Exposure up to 1000-hours. e/D = 1.5. Transverse direction only.



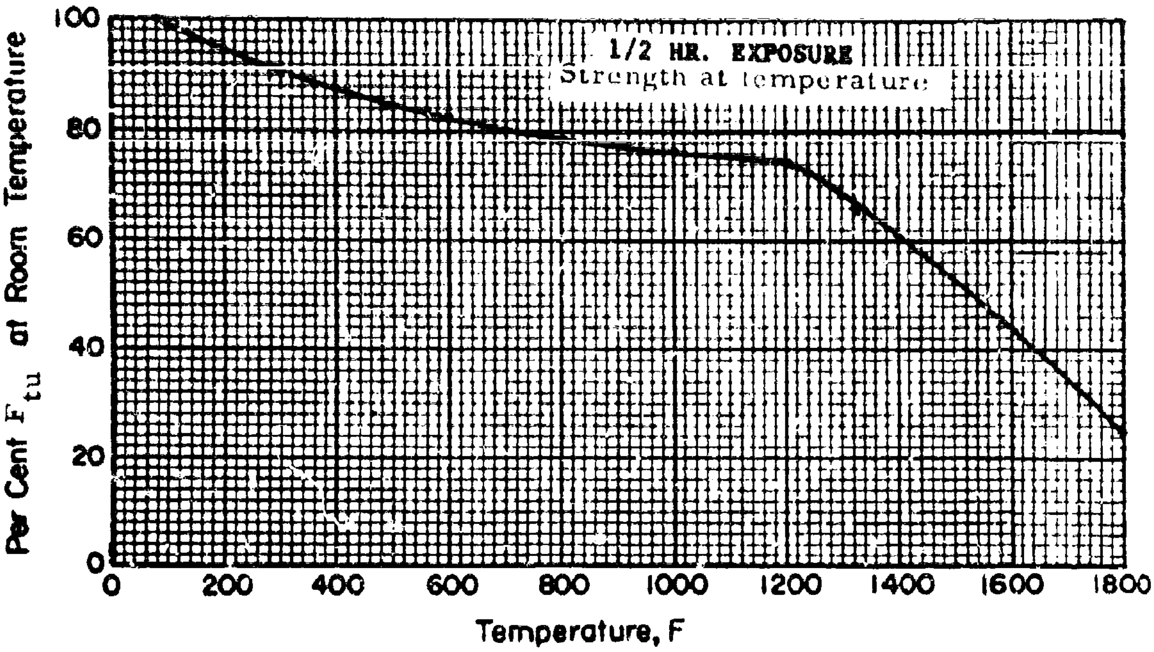
Effect of exposure at elevated temperature on the room temperature bearing yield strength (F_{bry}) of L-605 alloy sheet. Exposure up to 1000-hours. e/D = 1.5. Transverse direction only.



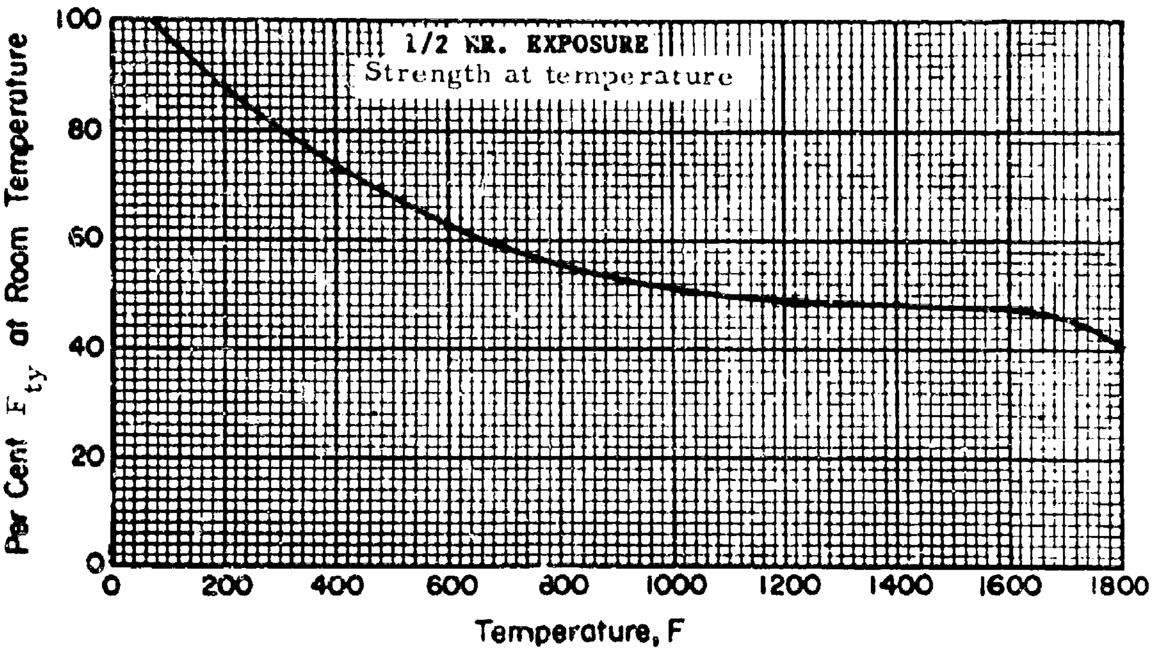
Effect of temperature on shear ultimate strength (F_{su}) of L-605 alloy sheet. Exposure up to 1/2-hour.



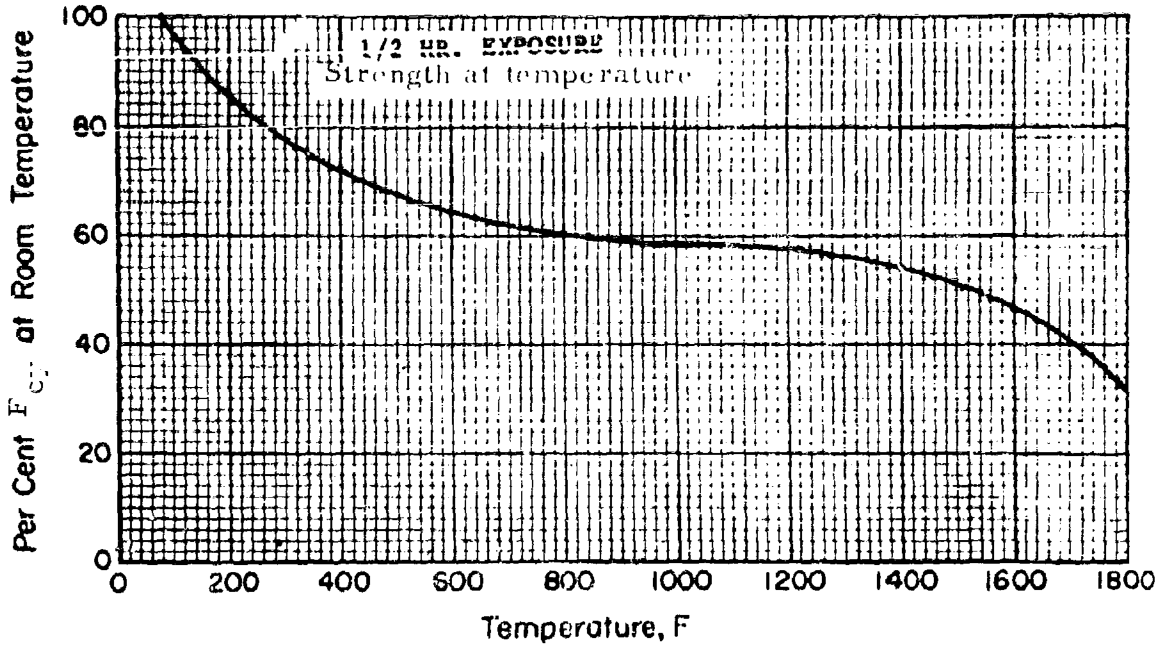
Effect of exposure time on the elevated temperature shear ultimate strength (F_{su}) of L-605 alloy sheet. Exposure up to 1000-hours.



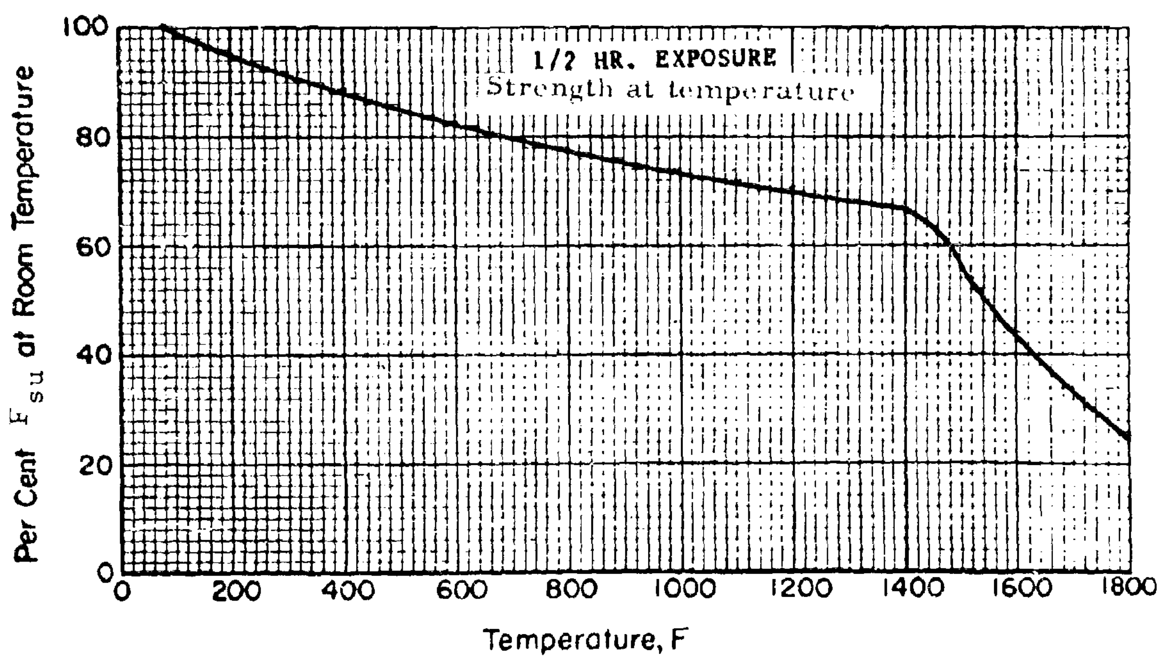
Effect of temperature on the ultimate tensile strength (F_{tu}) of L-605 alloy plate, bar and forgings. Exposure up to 1/2-hour.



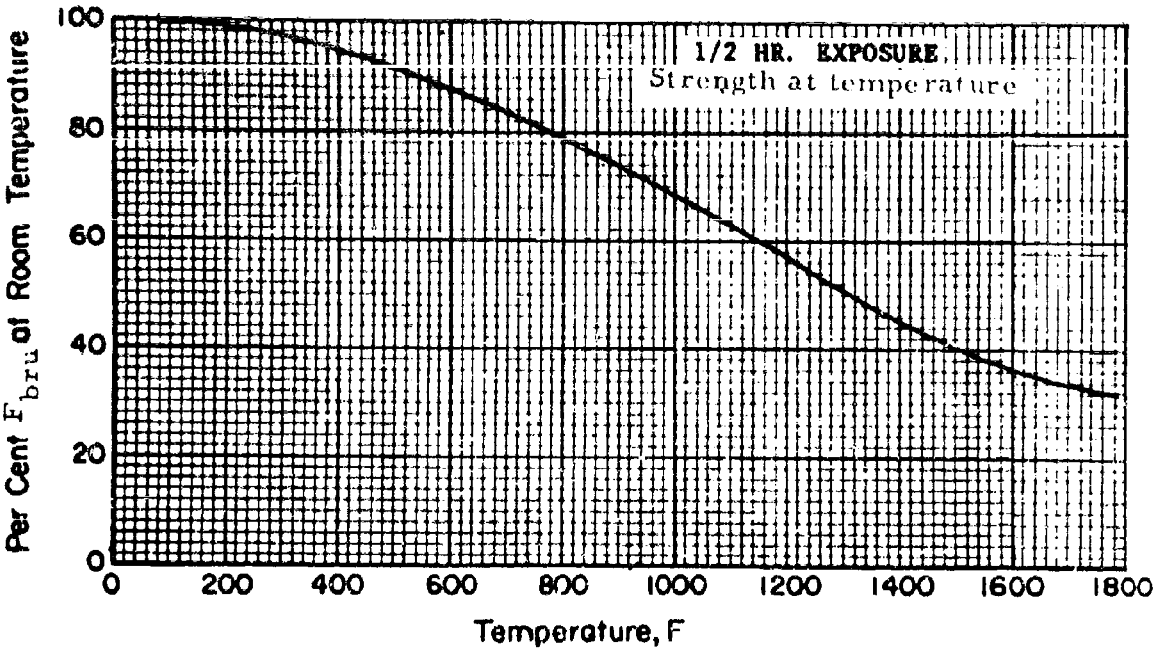
Effect of temperature on the tensile yield strength (F_{ty}) of L-605 alloy plate, bar and forgings. Exposure up to 1/2-hour.



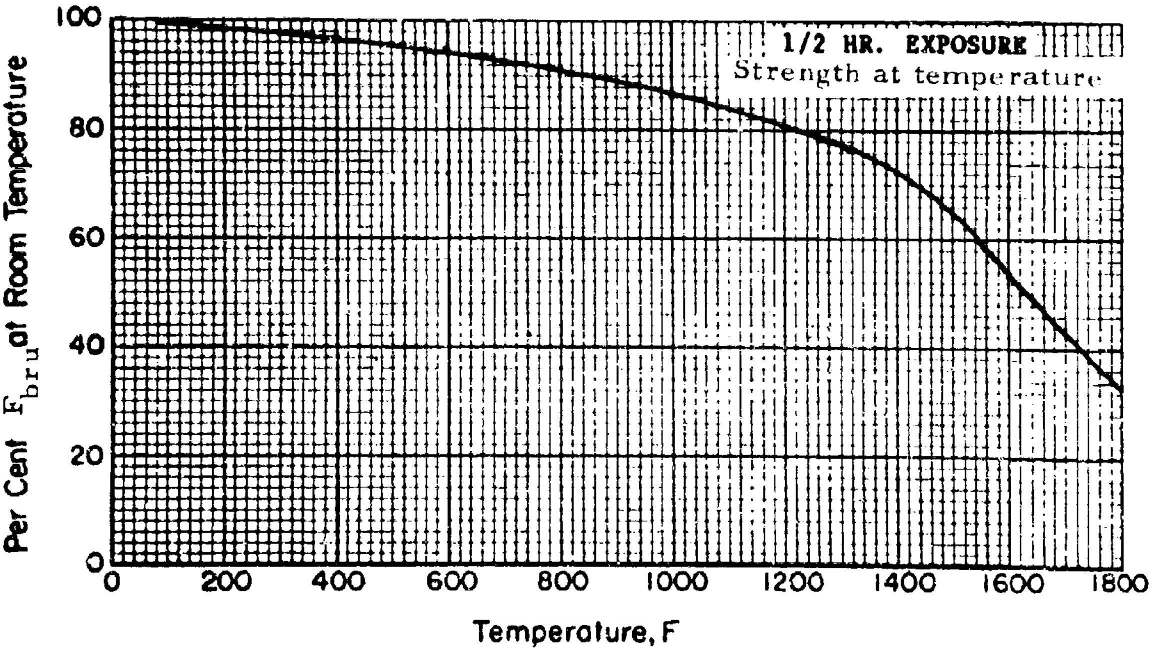
Effect of temperature on the compressive yield strength (F_{cy}) of L-605 alloy plate, bar and forgings. Exposure up to 1/2-hour.



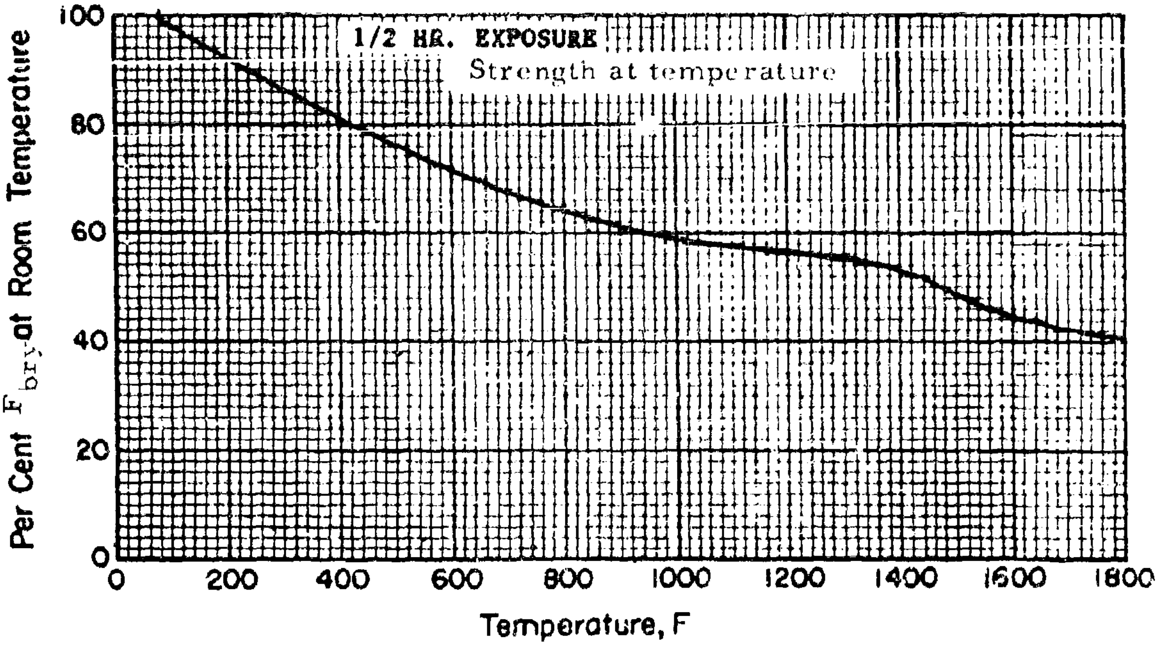
Effect of temperature on the shear ultimate strength (F_{su}) of L-605 alloy plate, bar and forgings. Exposure up to 1/2-hour.



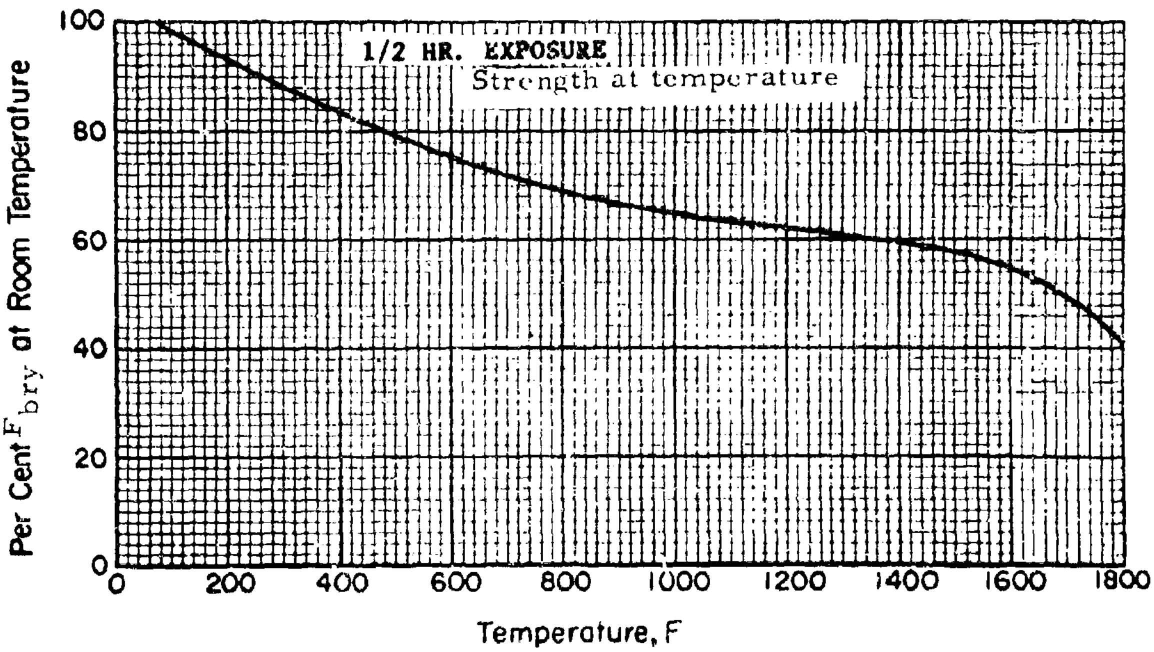
Effect of temperature on the bearing ultimate strength (F_{bru}) of L-605 alloy plate. Exposure up to 1/2-hour. e/D = 1.5.



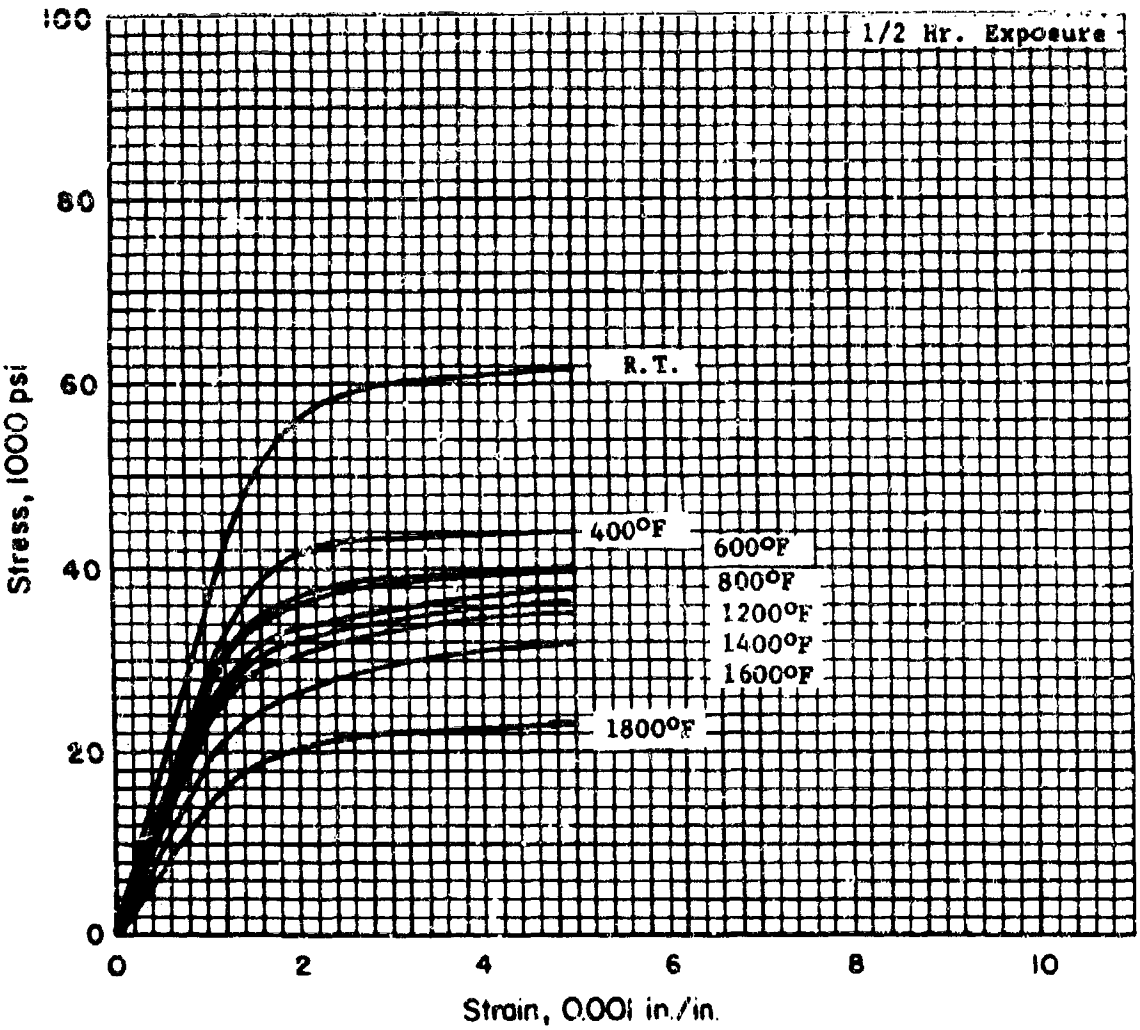
Effect of temperature on the bearing ultimate strength (F_{bru}) of L-605 alloy plate. Exposure up to 1/2-hour. e/D = 2.0.



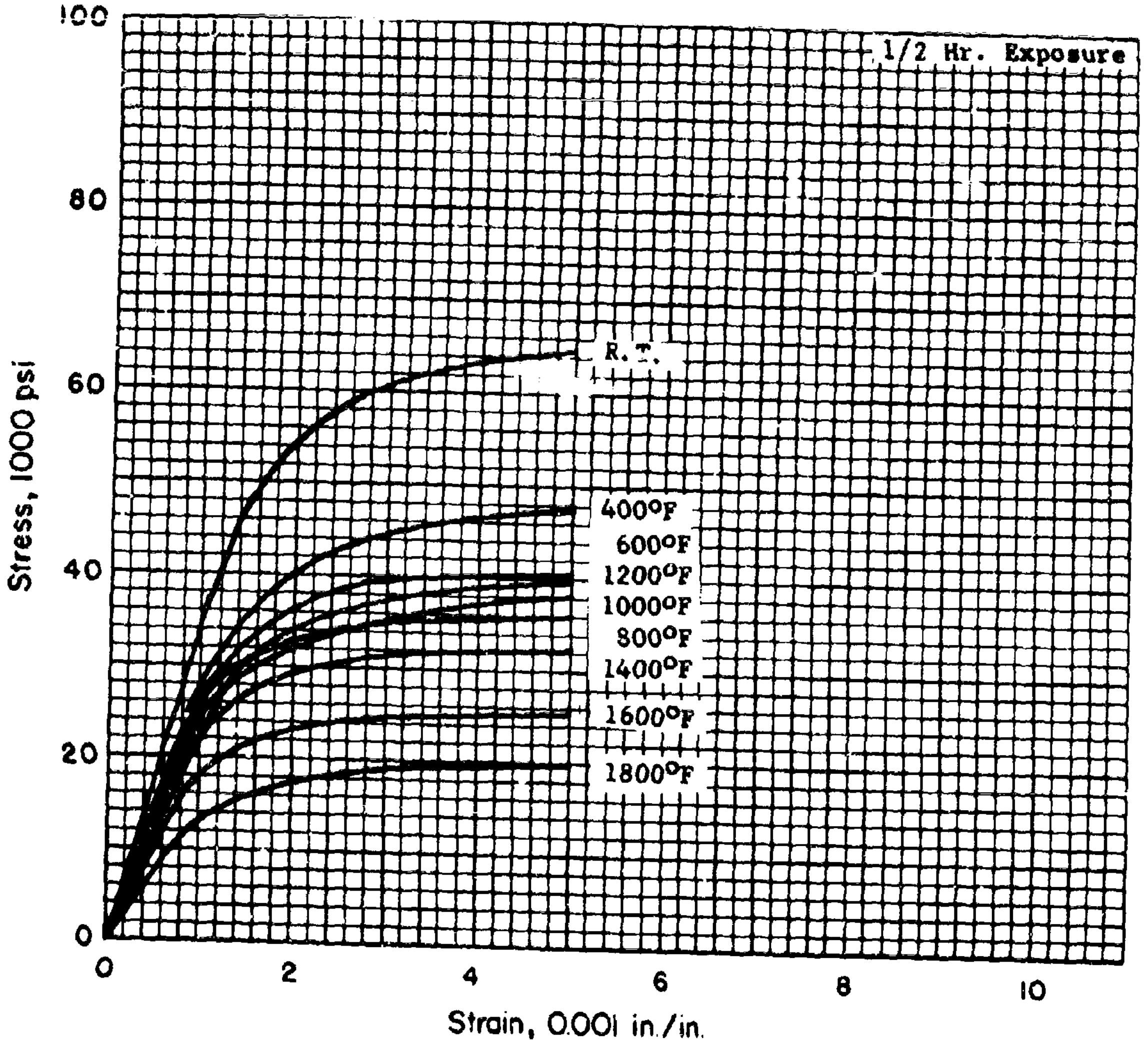
Effect of temperature on the bearing yield strength (F_{bry}) of L-605 alloy plate. Exposure up to 1/2-hour. e/D = 1.5.



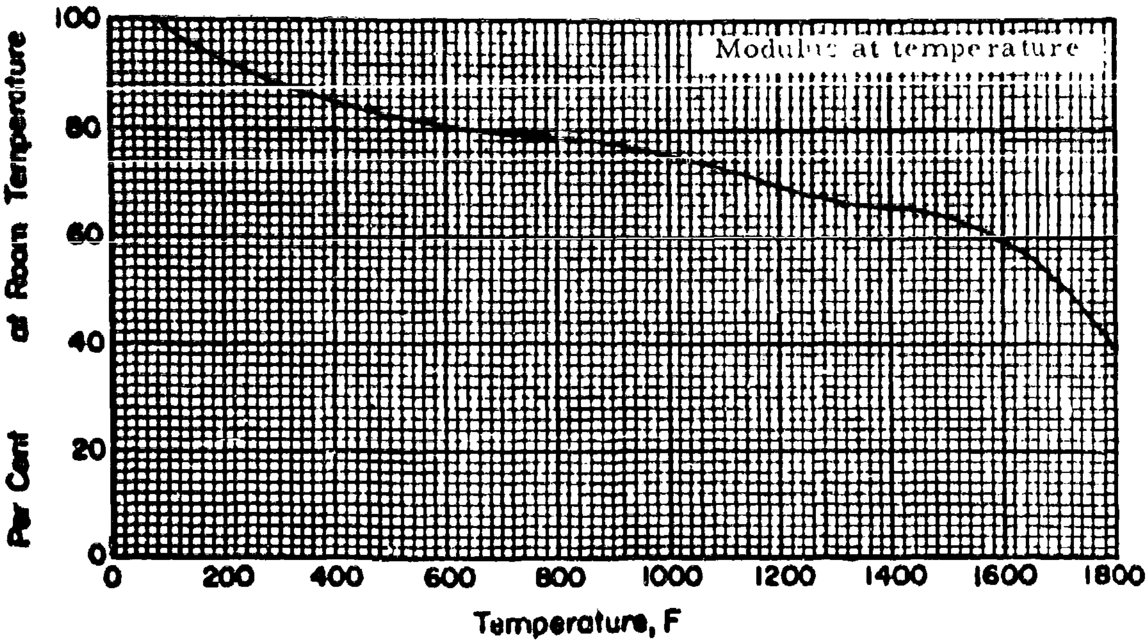
Effect of temperature on the bearing yield strength (F_{bry}) of L-605 alloy plate. Exposure up to 1/2-hour. e/D = 2.0.



Typical tensile stress vs. strain curves for L-605 alloy sheet. Transverse direction only.



Typical compressive stress vs. strain curves for L-605 alloy sheet. Transverse direction only.

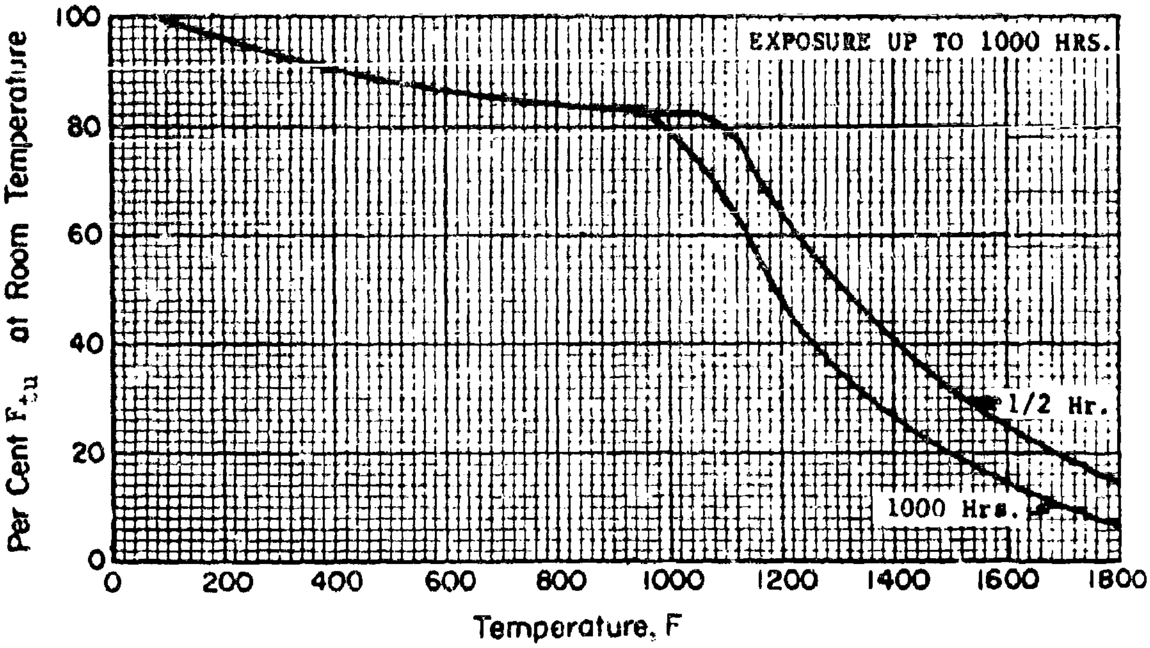


The effect of temperature on the elastic moduli, E and Ec, of L-605 alloy.

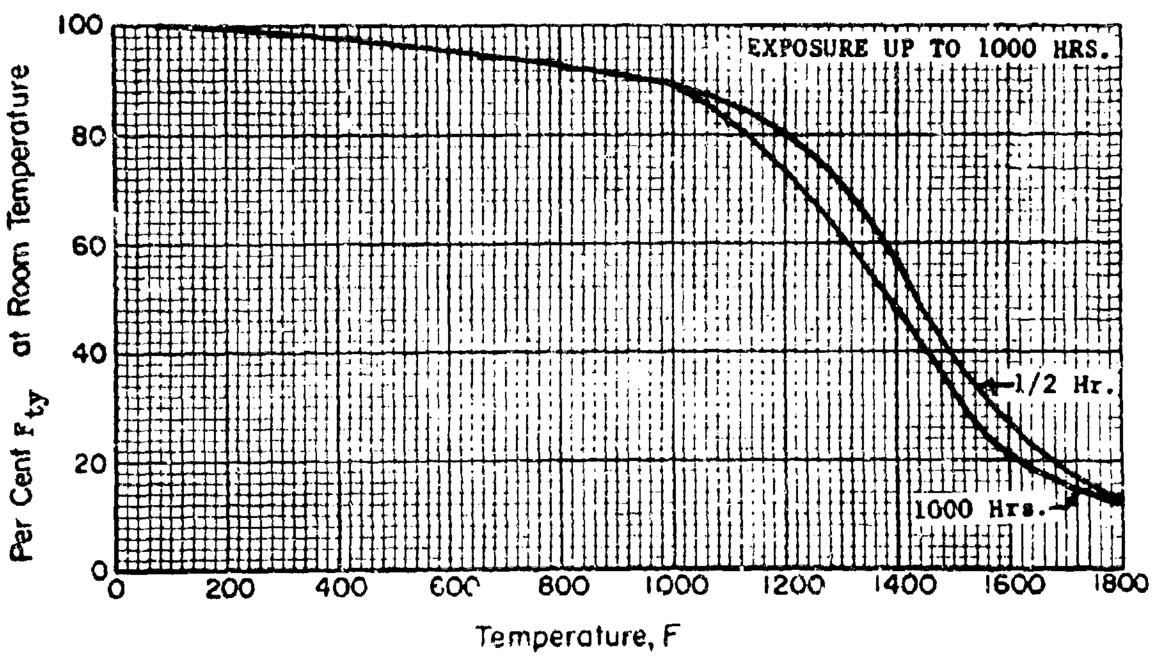
SECTION VIII - MIL-HDBK-5 DATA PRESENTATION

8.3 MATERIAL, INCONEL 702

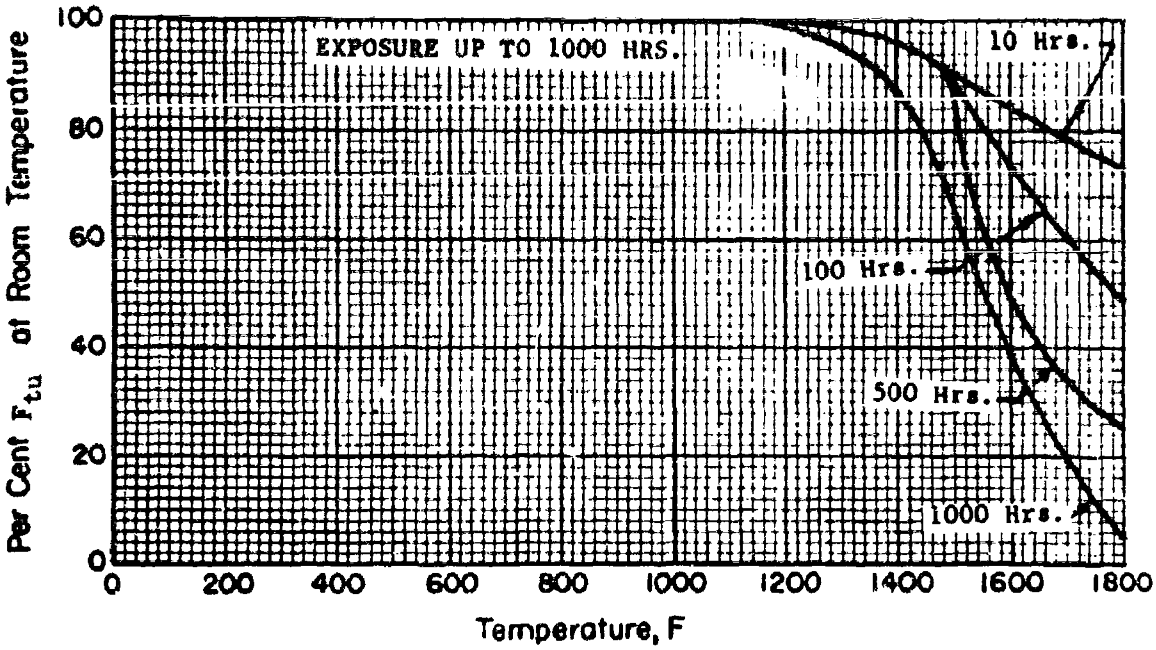
Alloy	Inconel 702				
Form	Sheet (.020" ≤ t ≤ .187")				
Condition	Solution Treated and Aged				
DIRECTION	L		T		
Basis	Tentative A	Tentative B	Tentative A	Tentative B	
Mechanical Properties					
F_{tu}, ksi	125.6	131.6	128.3	134.4	
F_{ty}, ksi	67.4	73.4	69.5	75.7	
F_{cy}, ksi	67.6	73.6	71.7	78.1	
F_{su}, ksi	94.5	99.0	94.4	98.9	
F_{bru}, ksi					
(e/D = 1.5)	191.7	200.8	190.8	199.9	
(e/D = 2.0)	234.7	246.0	241.3	252.8	
F_{bry}, ksi					
(e/D = 1.5)	103.6	112.8	105.8	115.3	
(e/D = 2.0)	129.3	140.9	128.7	140.2	
e, per cent					
E, 10^6 psi	32.6				
E_c, 10^6 psi	32.0				
G, 10^6 psi					
Physical Properties					
ω, lb/in.^{3}					
C, Btu/(lb)(F)					
K, Btu/[(hr)(ft^2)(F)/ft]					
α, 10^{-6} in./in./F					



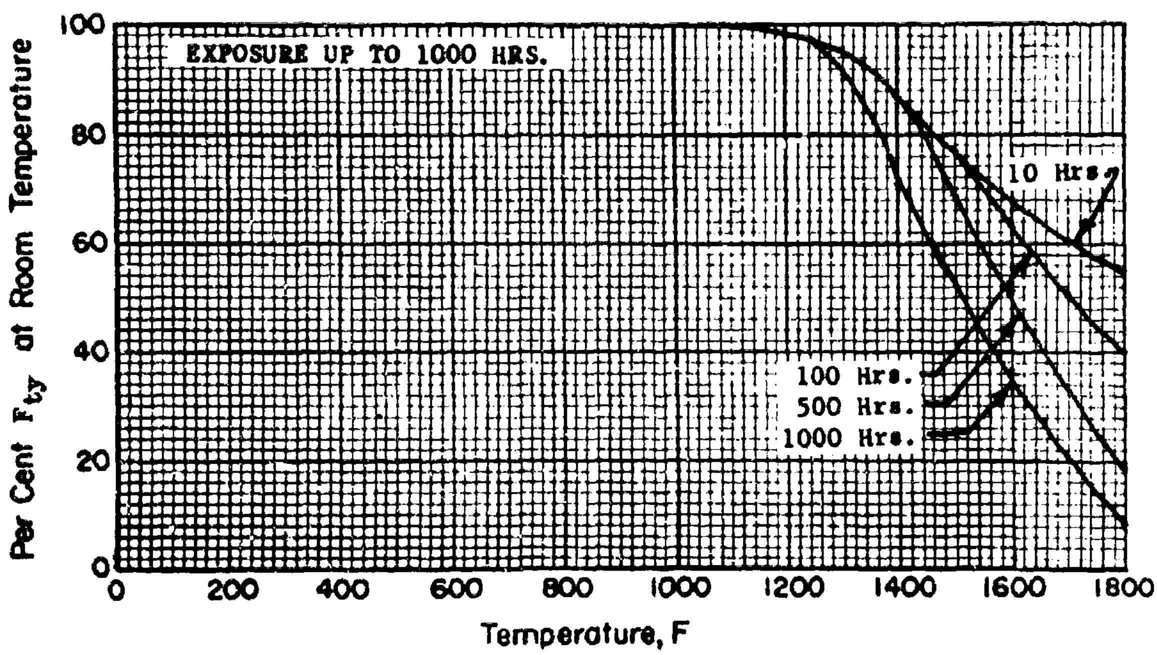
Effect of exposure temperature on the elevated temperature ultimate tensile strength (F_{tu}) of Inconel 702 alloy foil, Transverse direction. Exposure up to 1000-hours.



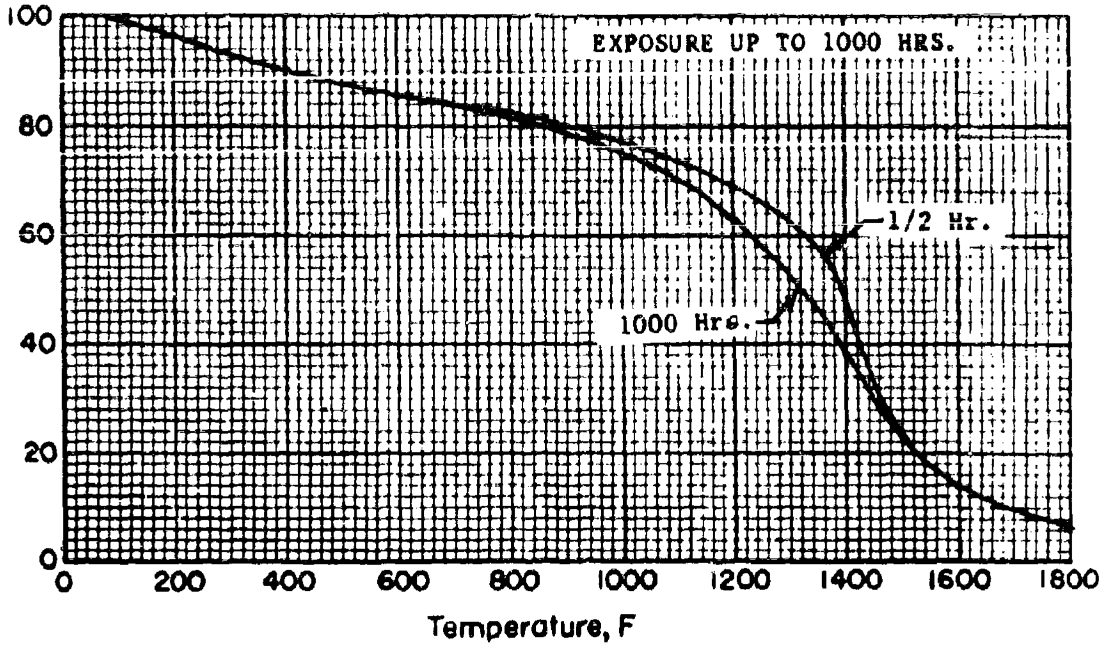
Effect of exposure temperature on the elevated temperature tensile yield strength (F_{ty}) of Inconel 702 alloy foil, Transverse direction. Exposure up to 1000-hours.



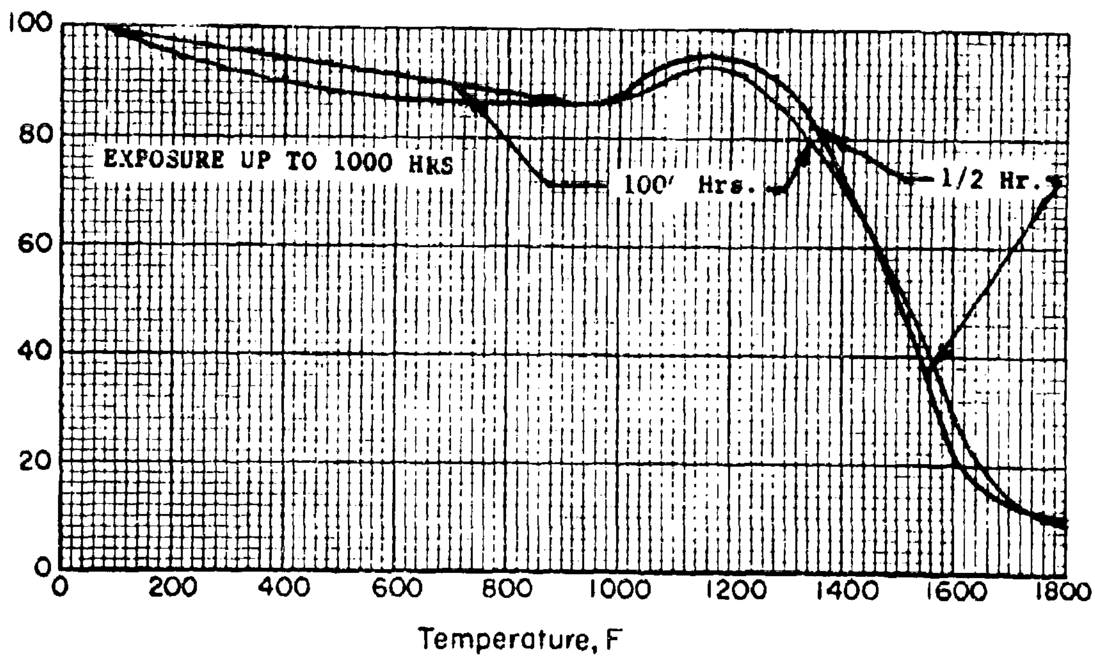
Effect of exposure temperature on room temperature ultimate tensile strength (F_{tu}) of Inconel 702 alloy foil, transverse direction. Exposure up to 1000-hours.



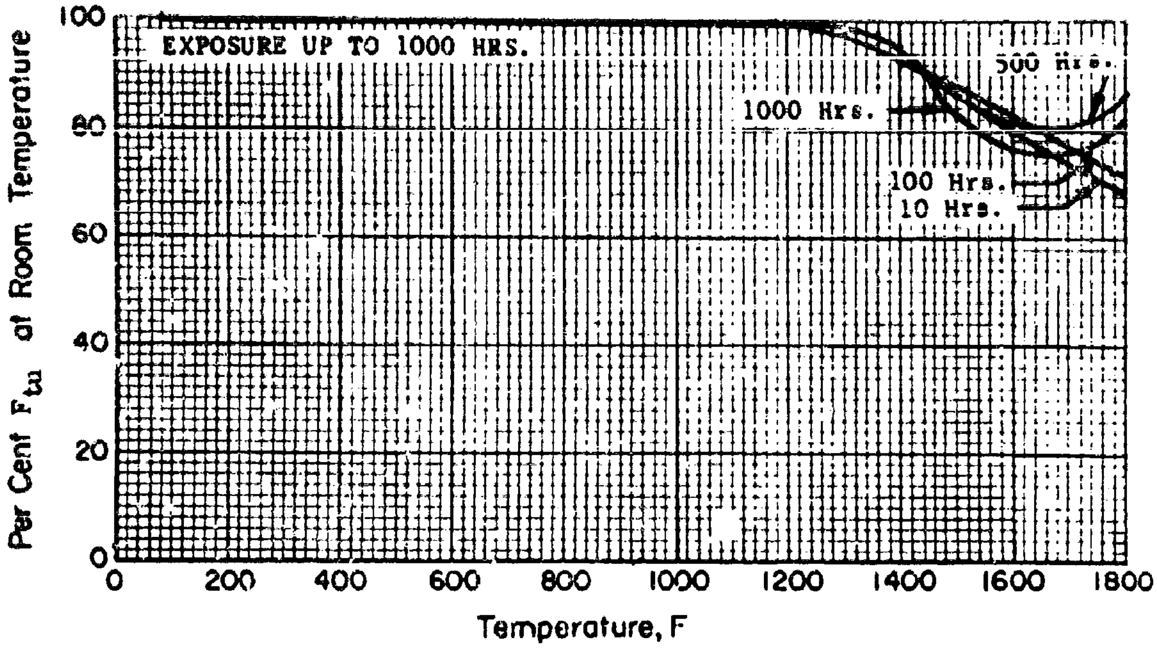
Effect of exposure temperature on room temperature tensile yield strength (F_{ty}) of Inconel 702 alloy foil, transverse direction. Exposure up to 1000-hours.



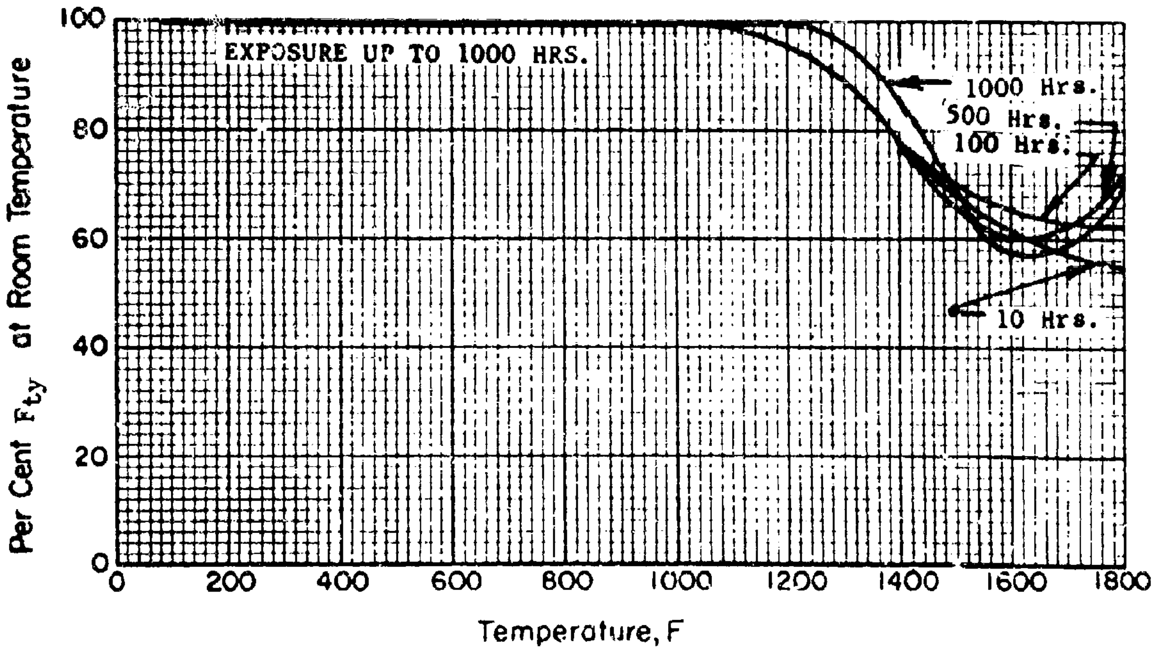
Effect of exposure temperature on the elevated temperature ultimate tensile strength (F_{tu}) of Inconel 702 alloy sheet, transverse direction. Exposure up to 1000-hours.



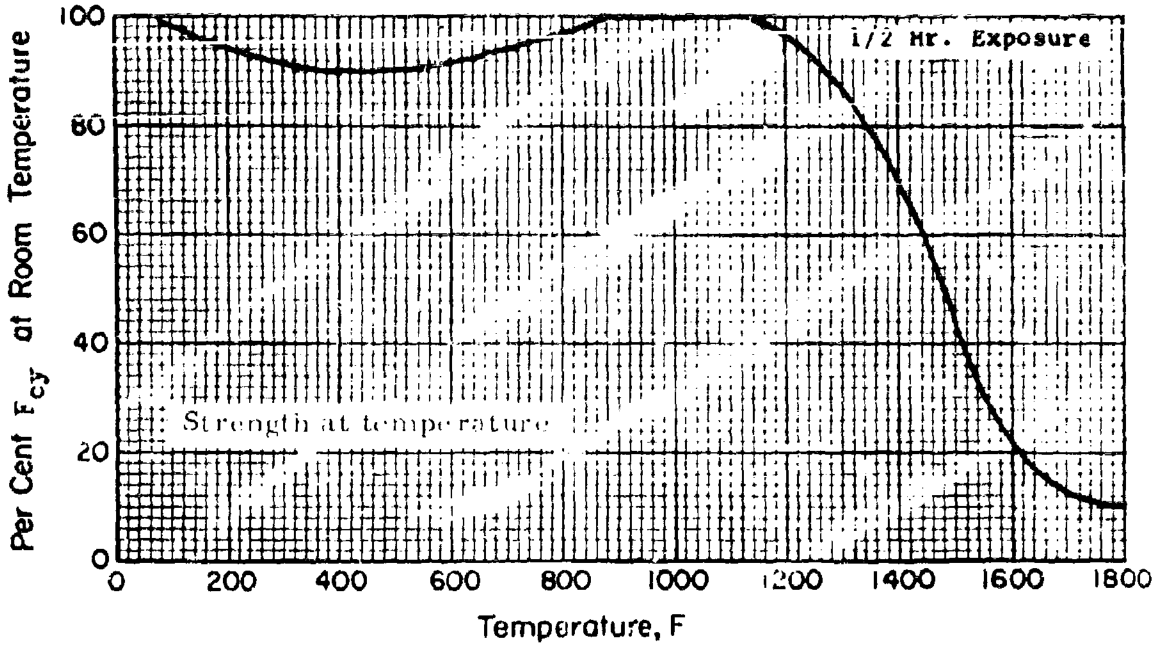
Effect of exposure temperature on the elevated temperature tensile yield strength (F_{ty}) of Inconel 702 alloy sheet, transverse direction. Exposure up to 1000-Hours.



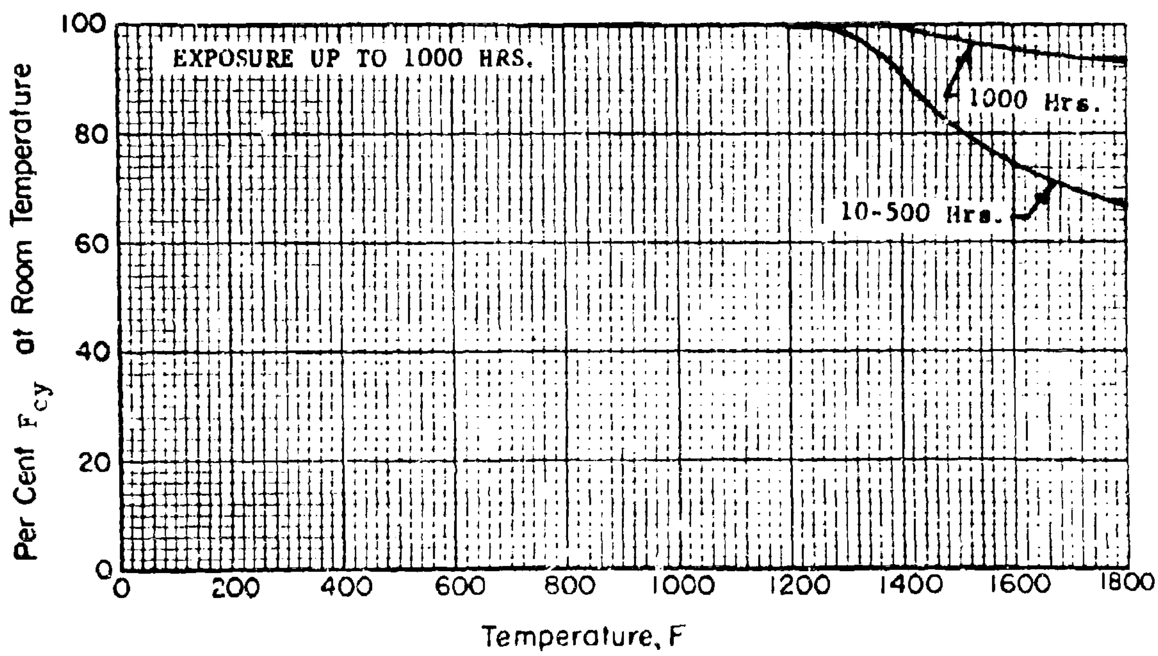
Effect of exposure temperature on the room temperature ultimate tensile strength (F_{tu}) of Inconel 702 alloy sheet, transverse direction. Exposure up to 1000-hours.



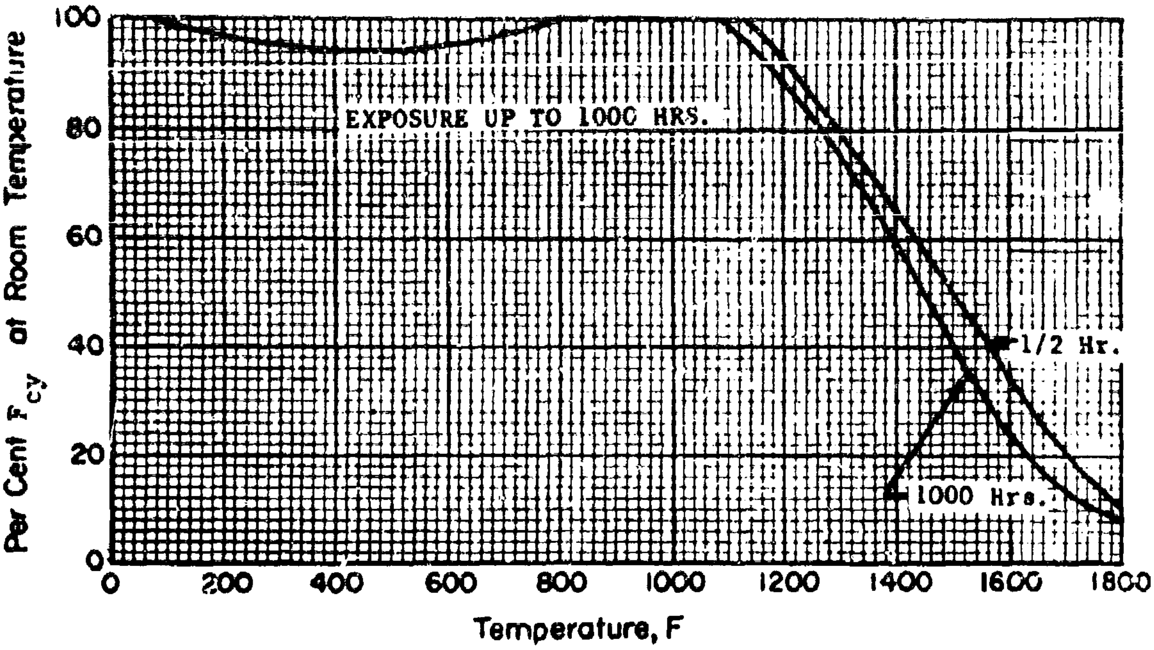
Effect of exposure temperature on the room temperature tensile yield strength (F_{ty}) of Inconel 702 alloy sheet, transverse direction. Exposure up to 1000-hours.



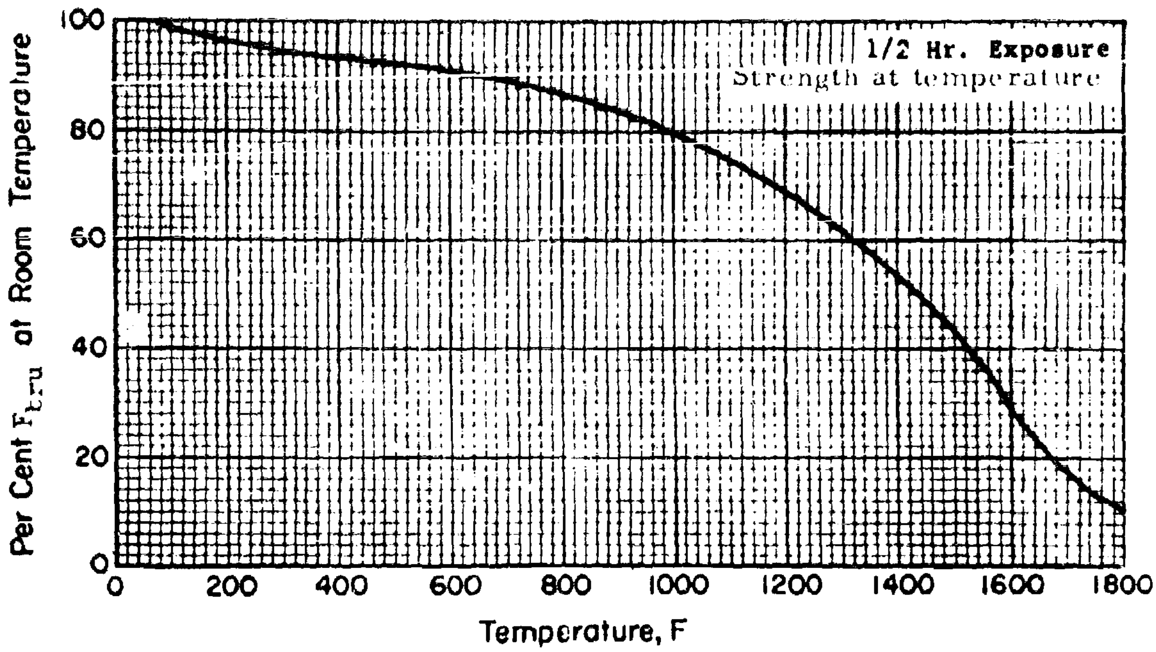
Effect of temperature on the compression yield strength (F_{cy}) of Inconel 702 alloy sheet, transverse and longitudinal directions. Exposure up to 1/2-hour.



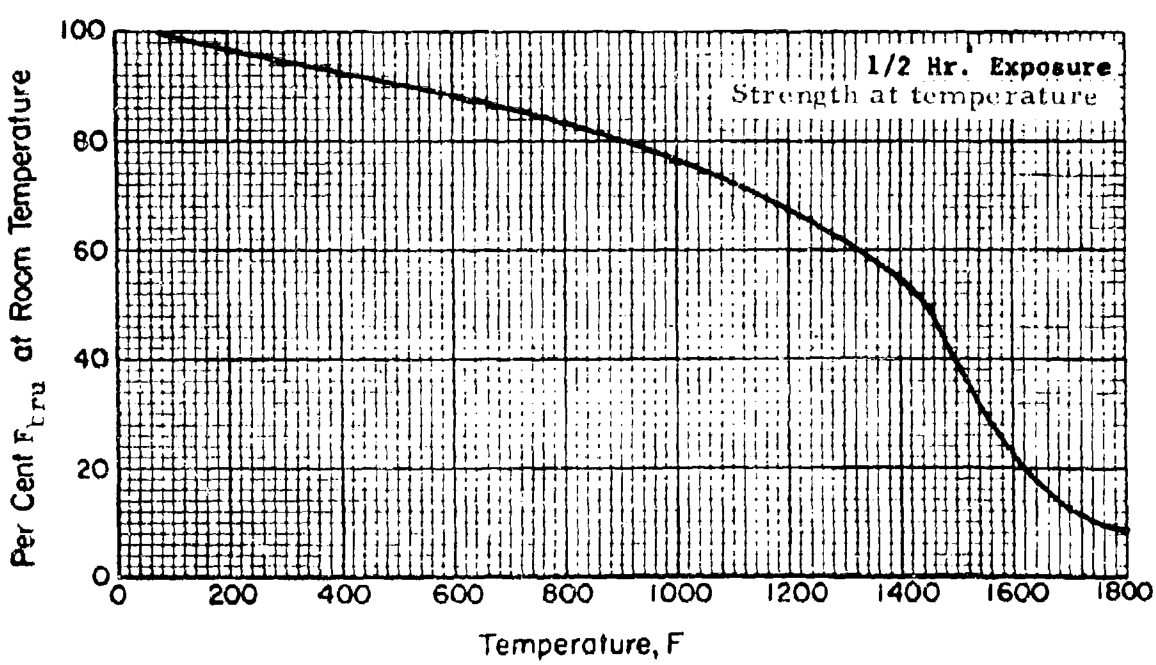
Effect of exposure temperature on room temperature compression yield strength (F_{cy}) of Inconel 702 alloy sheet, transverse direction. Exposure up to 1000-hours.



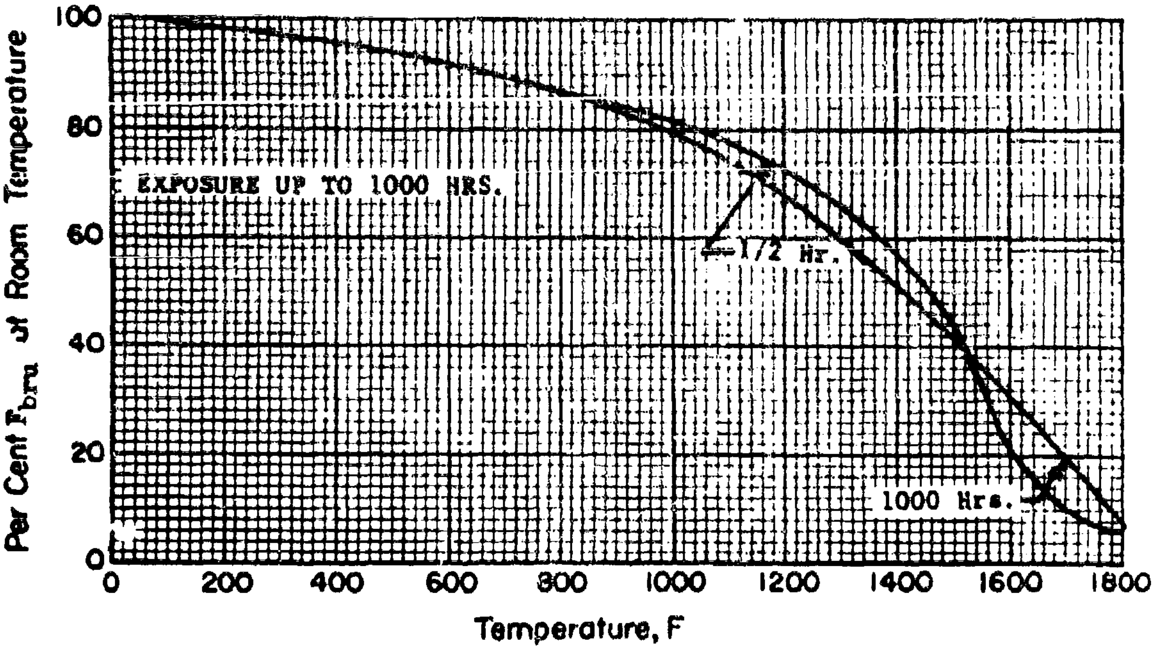
Effect of exposure temperature on elevated temperature on elevated temperature compression yield strength (F_{cy}) of Inconel 702 alloy sheet, transverse direction. Exposure up to 1000-hours.



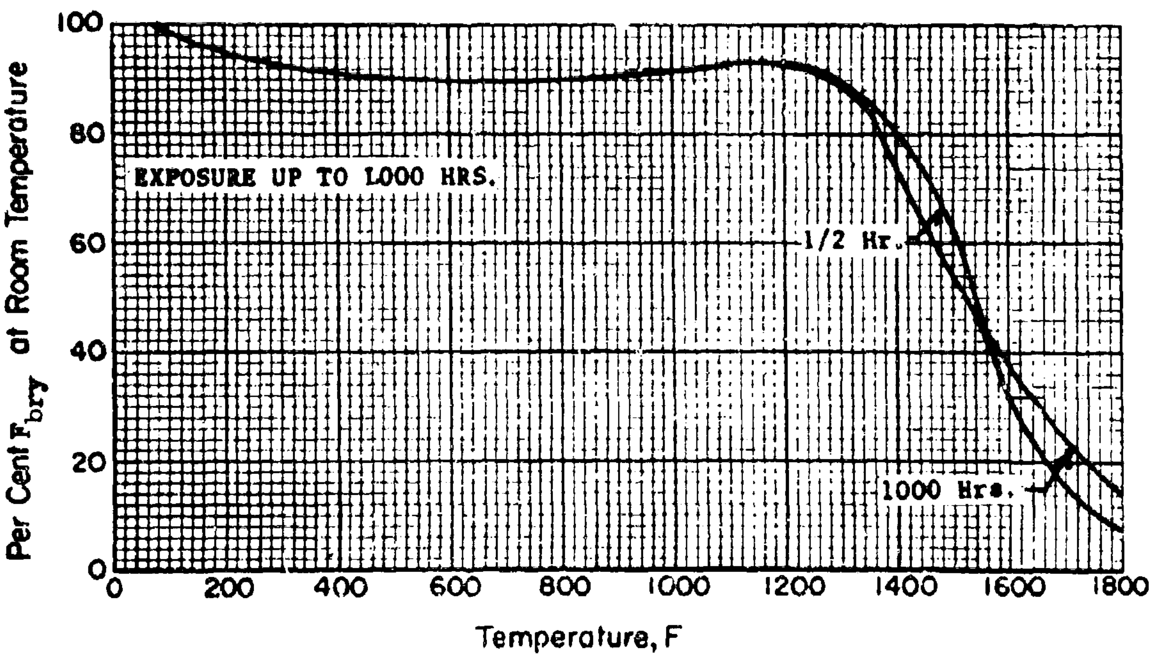
Effect of temperature on the bearing ultimate strength (F_{bru}) of Inconel 702 alloy sheet, transverse and longitudinal directions, e/D = 1.5. Exposure up to 1/2-hour.



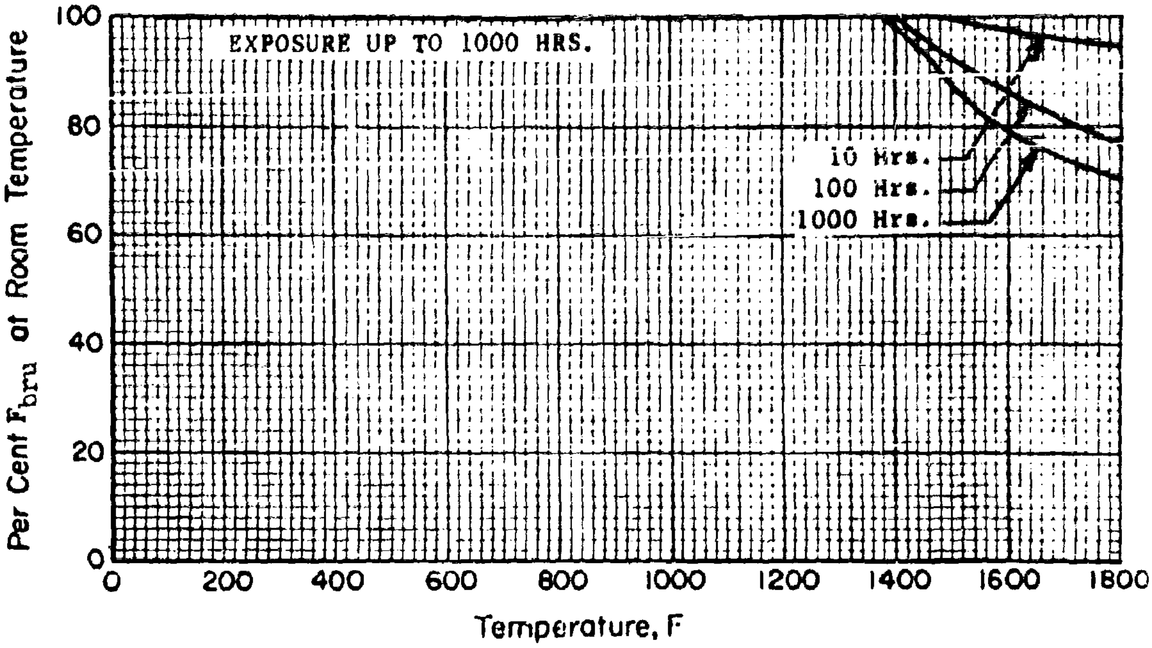
Effect of temperature on the bearing ultimate strength (F_{bru}) of Inconel 702 alloy sheet, transverse and longitudinal directions, e/D = 2.0. Exposure up to 1/2-hour.



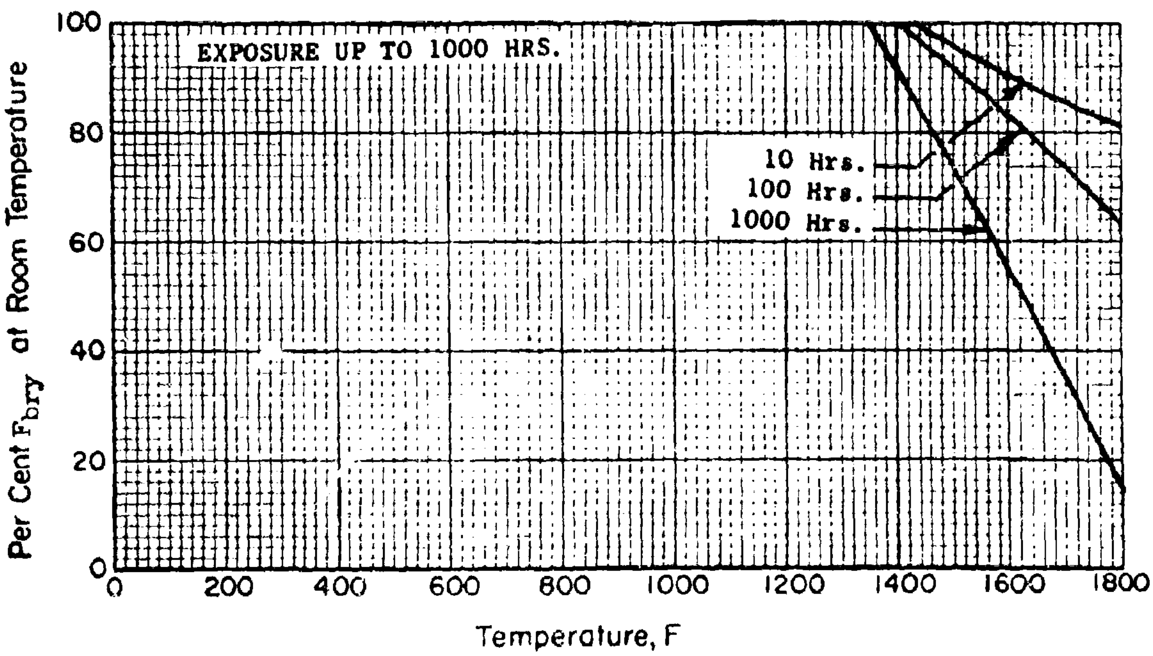
Effect of exposure temperature on the elevated temperature bearing ultimate strength (F_{bru}) of Inconel 702 alloy sheet, transverse direction, e/D = 1.5. Exposure up to 1000-hours.



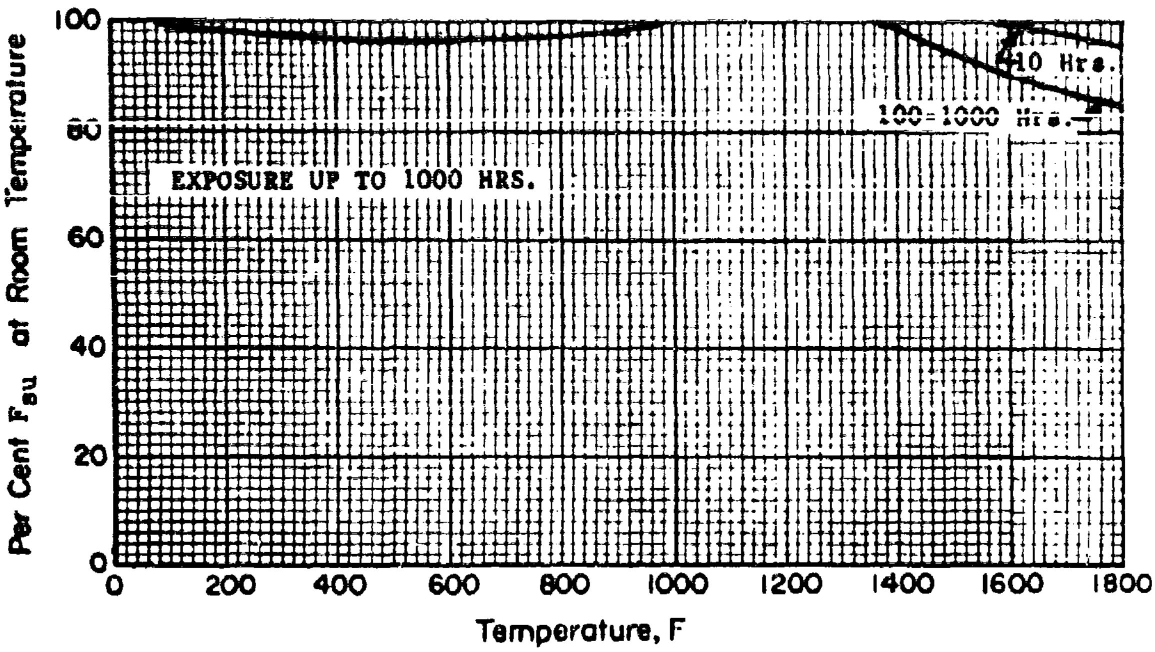
Effect of exposure temperature on elevated temperature bearing yield strength (F_{bry}) of Inconel 702 alloy sheet, transverse direction, e/D = 1.5. Exposure up to 1000-hours.



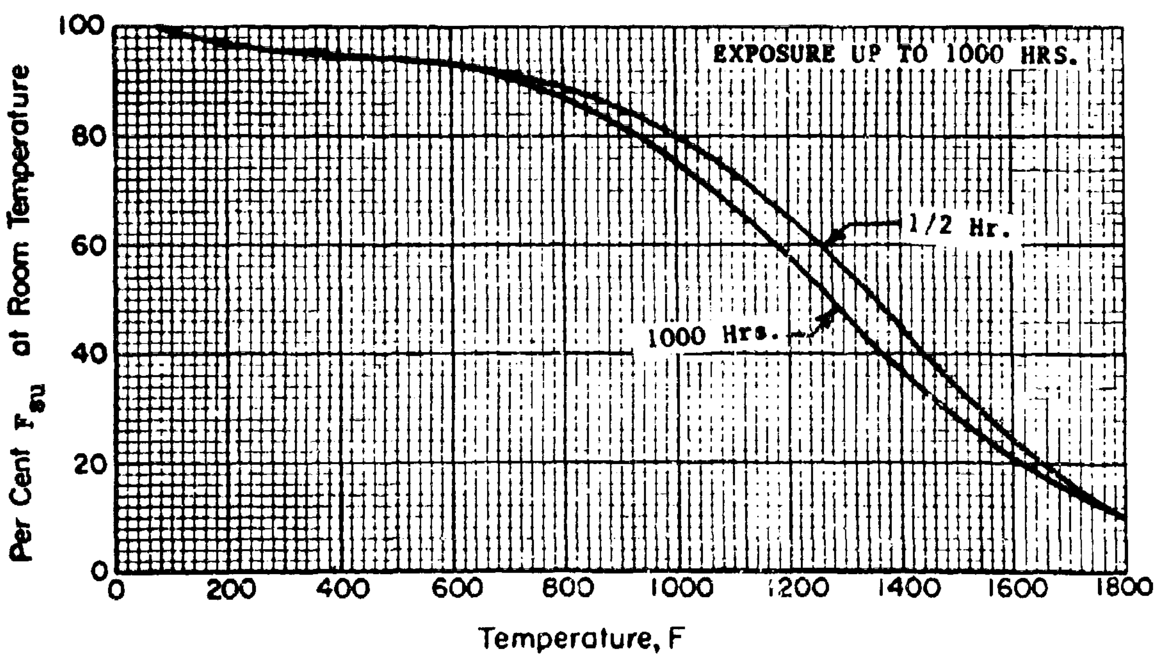
Effect of exposure temperature on the room temperature bearing ultimate strength (F_{bru}) of Inconel 702 alloy sheet, transverse direction, e/D = 1.5. Exposure up to 1000-hours.



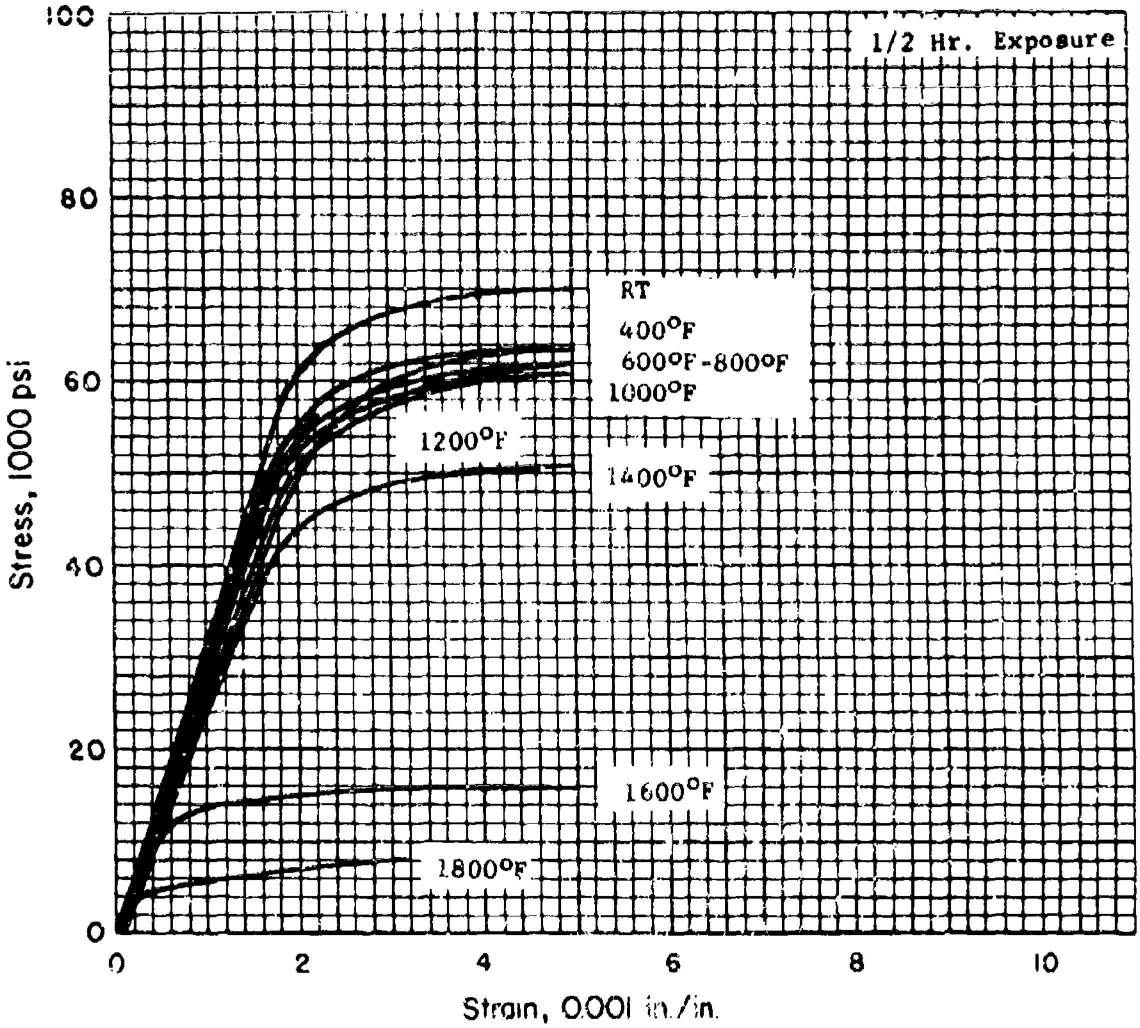
Effect of exposure temperature on the room temperature bearing yield strength (F_{bry}) of Inconel 702 alloy sheet, transverse direction, e/D = 1.5. Exposure up to 1000-hours.



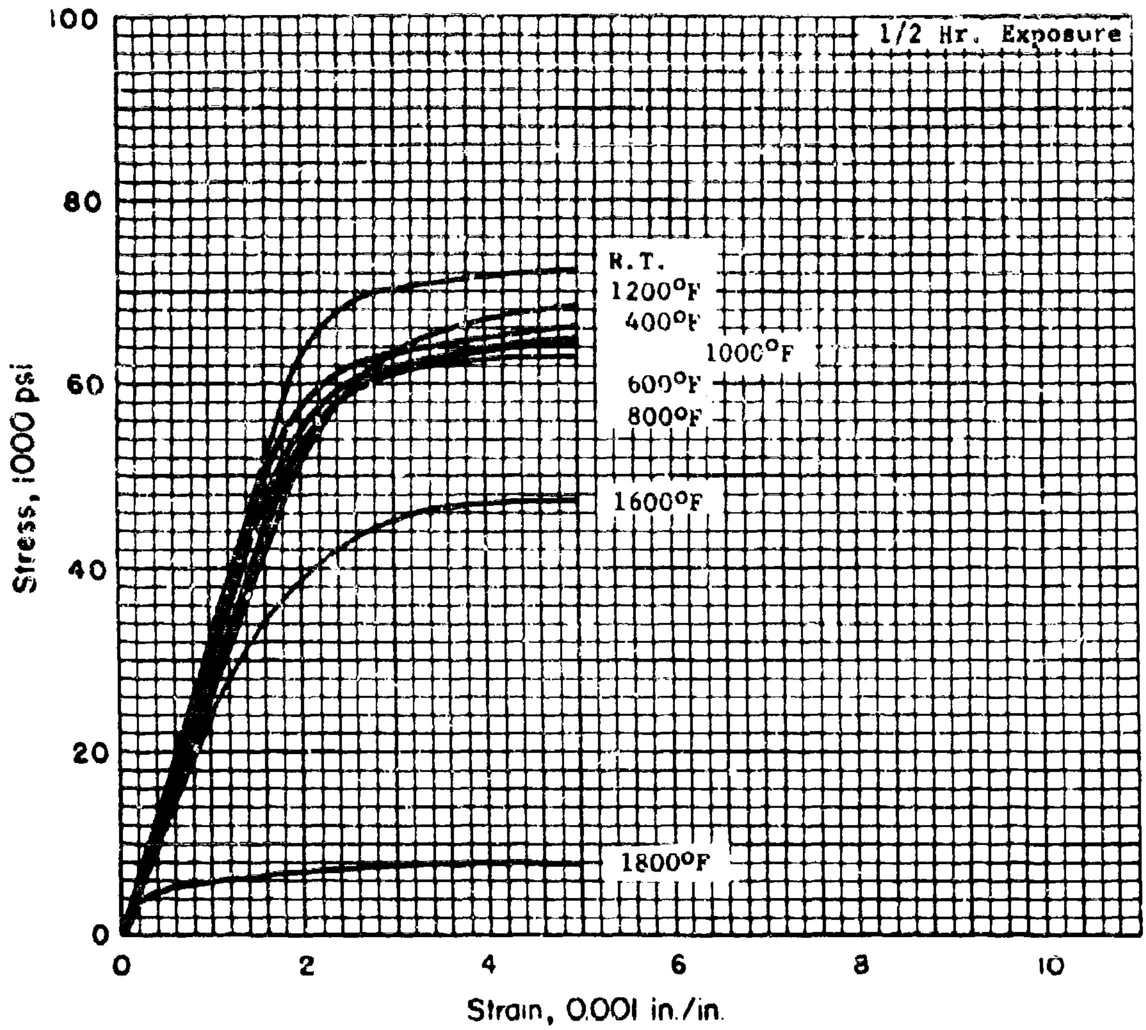
Effect of exposure temperature on the room temperature shear ultimate strength (F_{su}) of Inconel 702 alloy sheet, transverse and longitudinal directions. Exposure up to 1000-hours.



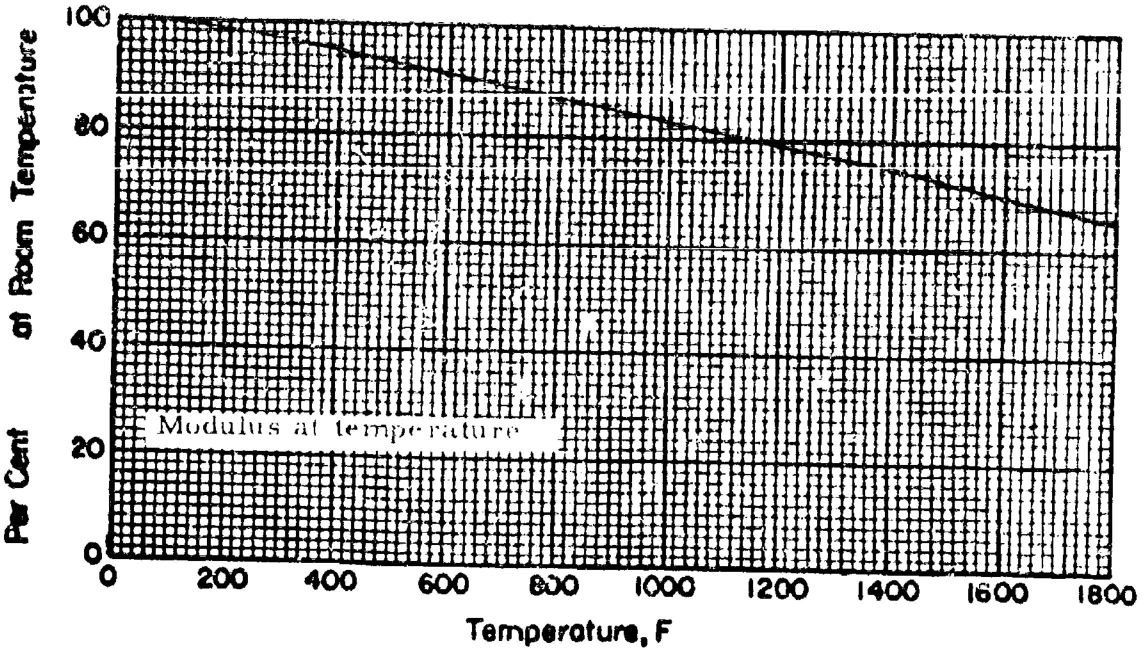
Effect of exposure temperature on the elevated temperature shear ultimate strength (F_{su}) of Inconel 702 alloy sheet, transverse and longitudinal directions. Exposure up to 1000-hours.



Typical tensile stress vs. strain curves for Inconel 702 alloy sheet. Transverse direction only.



Typical compressive stress vs. strain curves for Inconel 702 alloy sheet. Transverse direction only.



The effect of temperature on the elastic moduli, E and Ec, of Inconel 702 alloy

SECTION VIII - MIL-HDBK-5 DATA PRESENTATION

8.4 MATERIAL, INCOLOY 901

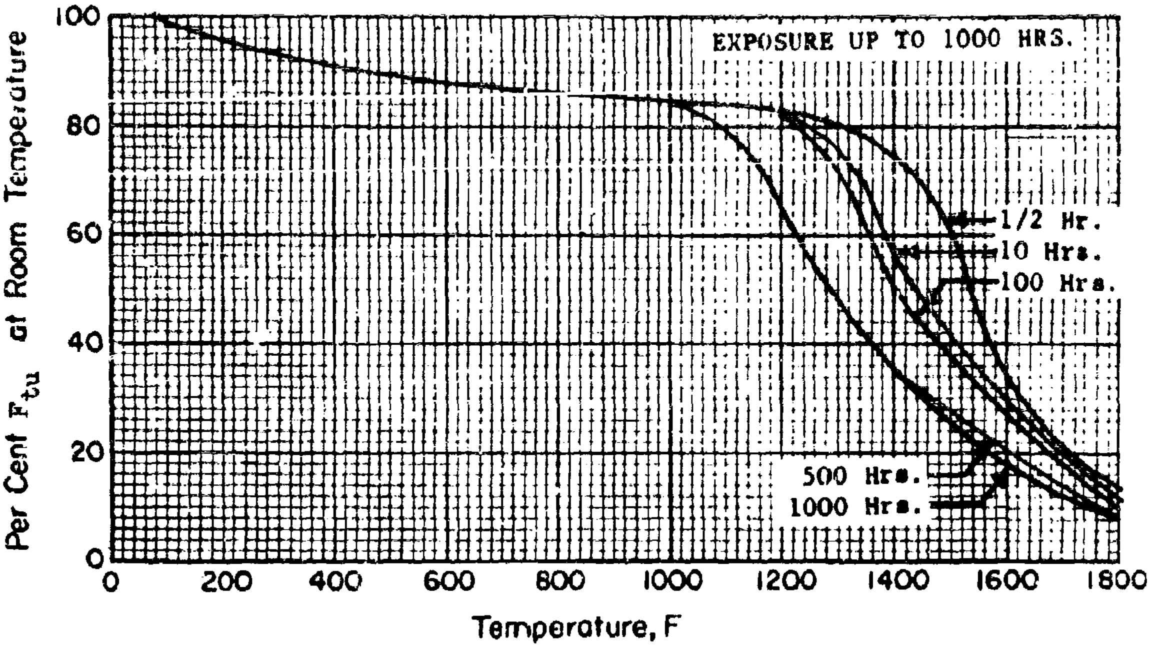
TABLE DESIGN MECHANICAL AND PHYSICAL PROPERTIES OF

Alloy	Incoloy 901					
Form	Forging				Bar	
Condition	Solution Treated and Double Aged					
DIRECTION	L		T		T	
Basis	A	B	A	B	Tentative A	B
Mechanical Properties						
F_{tu}, ksi						
F_{ty}, ksi						
F_{cy}, ksi			96.0	104.9		
F_{su}, ksi	108.8	112.7	104.2	107.9	99.1	102.7
F_{bru}, ksi						
(e/D = 1.5)						
(e/D = 2.0)						
F_{bry}, ksi						
(e/D = 1.5)						
(e/D = 2.0)						
e, per cent						
E, 10^6 psi	29.9				29.9	
E_c, 10^6 psi	29.9				29.9	
G, 10^6 psi						
Physical Properties						
ω, lb/in.^{3}						
C, Btu/(lb)(F)						
K, Btu/[(hr)(ft^2)(F)/ft]						
α, 10^{-6} in./in./F						

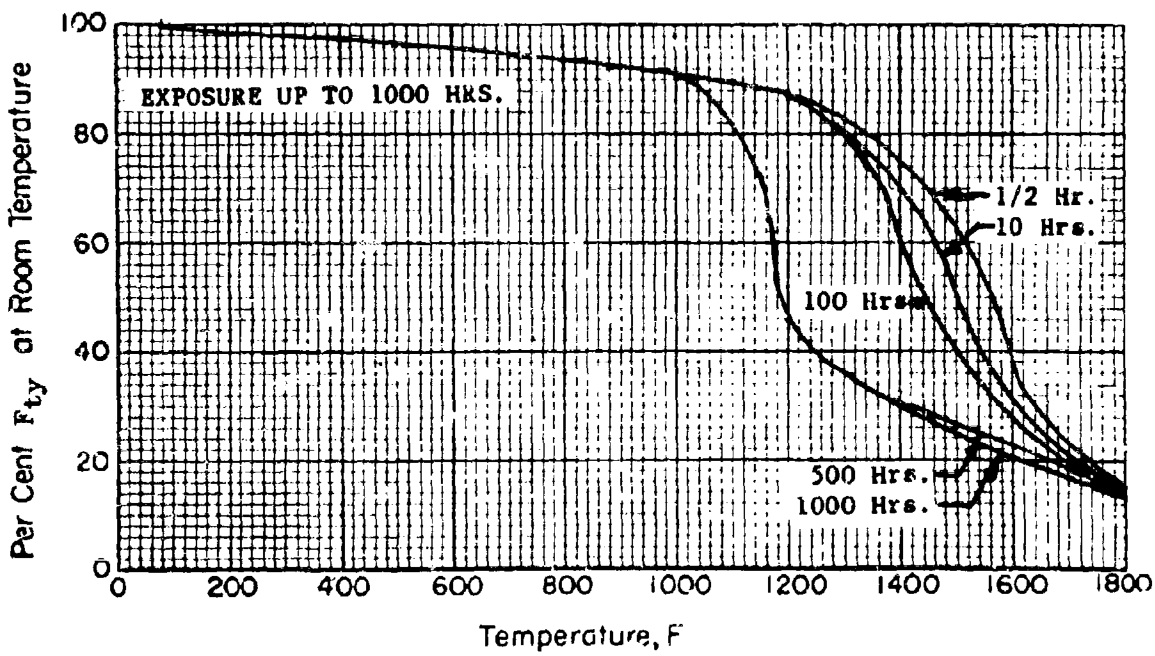
TABLE DESIGN MECHANICAL AND PHYSICAL PROPERTIES OF

Alloy	Incoloy 901				
Form	Bar				
Condition	Solution Treated and Double Aged				
DIRECTION	L		T		
Basis	A	B	A	B	
Mechanical Properties					
F_{tu}, ksi	162.2	168.0	148.4	153.7	
F_{ty}, ksi	101.7	111.1	95.8	104.7	
F_{cy}, ksi	102.1	111.5			
F_{su}, ksi			99.1*	102.7*	
F_{bru}, ksi					
(e/D = 1.5)					
(e/D = 2.0)					
F_{bry}, ksi					
(e/D = 1.5)					
(e/D = 2.0)					
e, per cent					
E, 10^6 psi	29.9				
E_c, 10^6 psi	29.9				
G, 10^6 psi					
Physical Properties					
ω, lb/in.^{3}					
C, Btu/(lb)(F)					
K, Btu/[(hr)(ft^2)(F)/ft]					
α, 10^{-6} in./in./F					

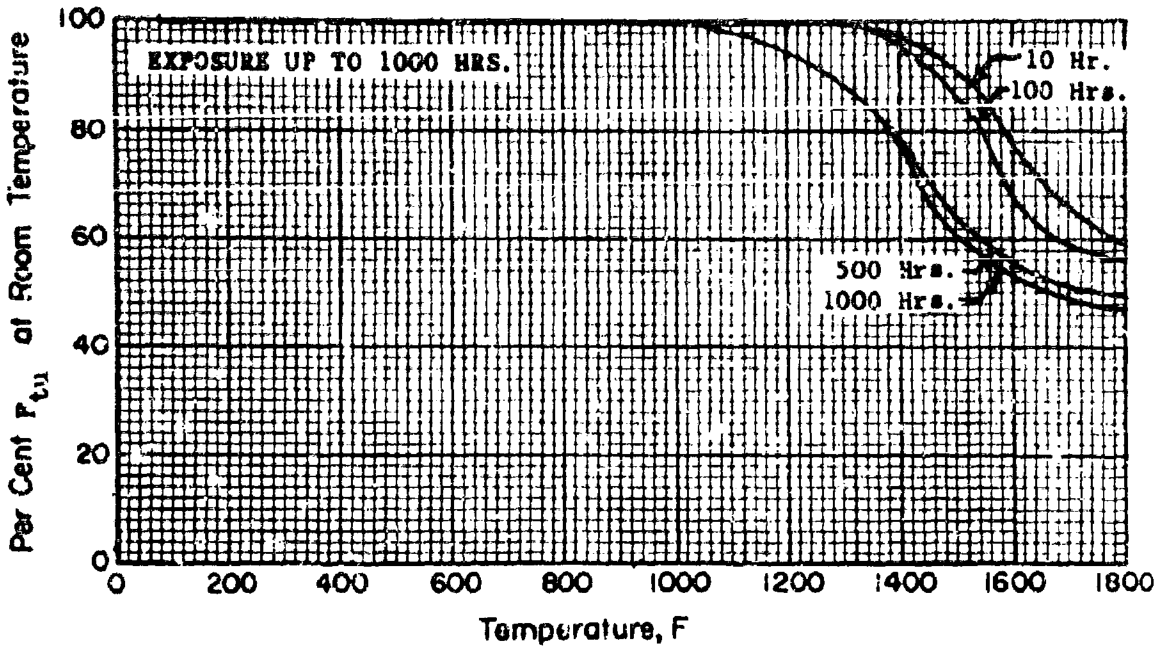
* Tentative



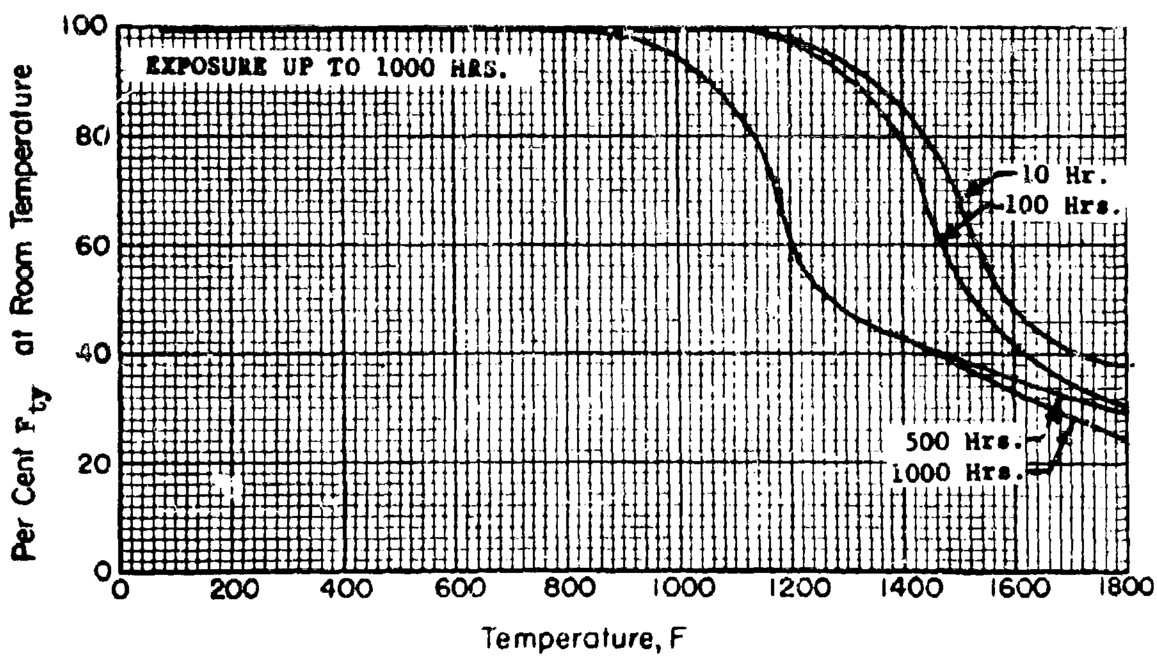
Effect of exposure temperature on the elevated temperature ultimate tensile strength (F_{tu}) of Incoloy 901 alloy bar, longitudinal direction. Exposure up to 1000-hours.



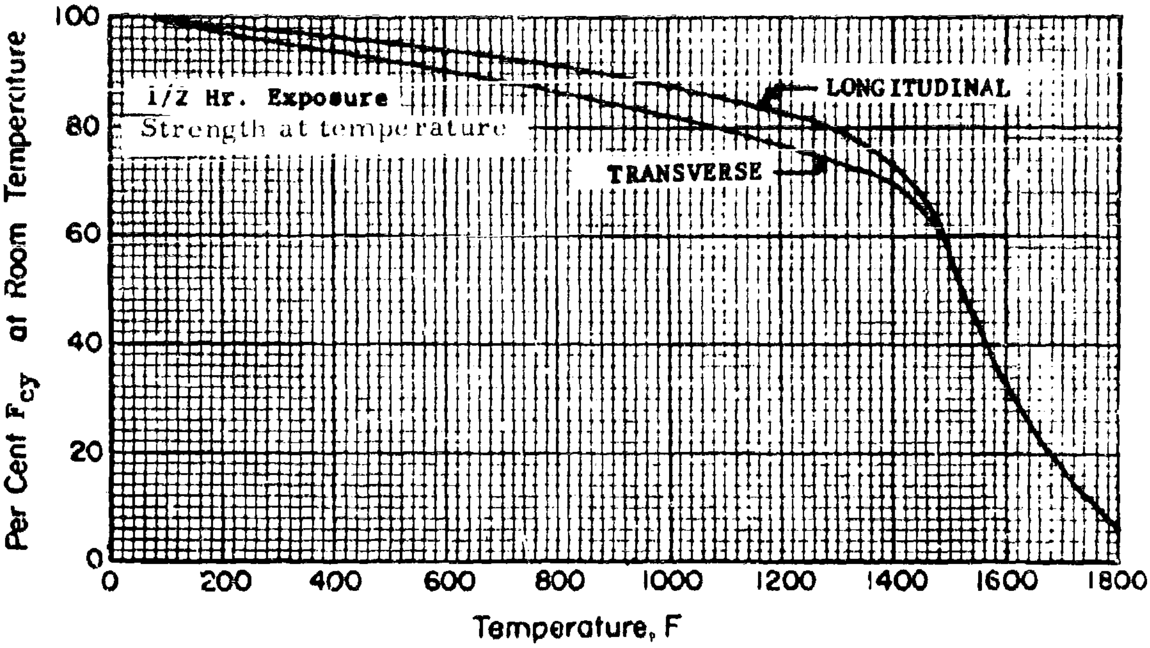
Effects of exposure temperature on the elevated temperature tensile yield strength (F_{ty}) of Incoloy 901 alloy bar, longitudinal direction. Exposure up to 1000-hours.



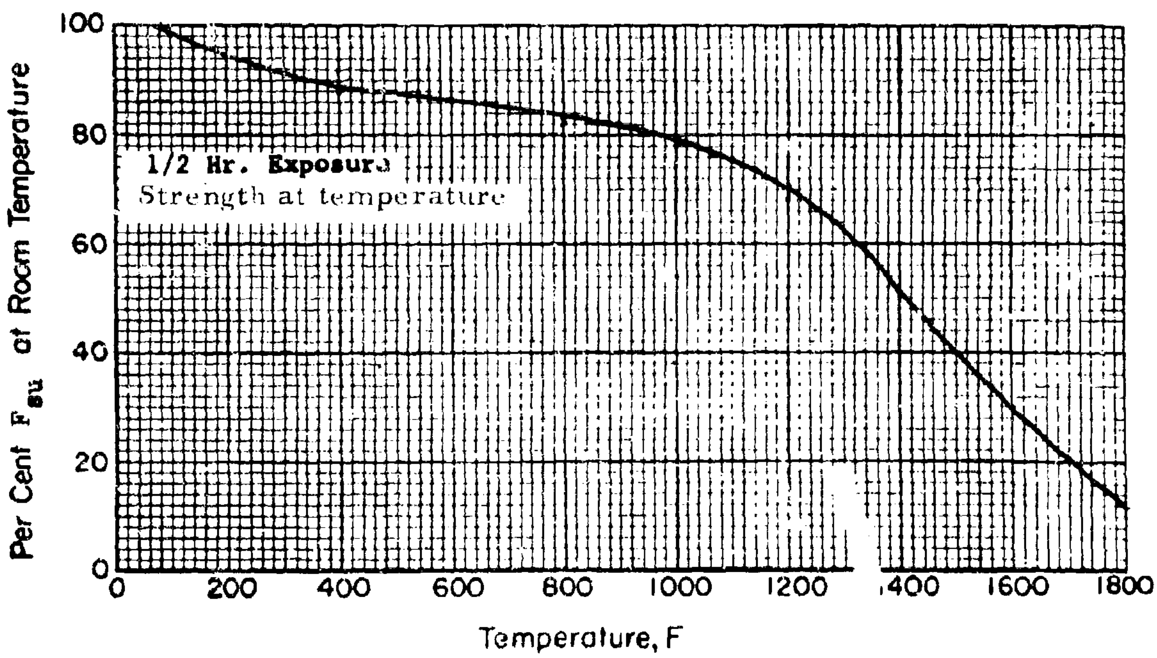
Effect of exposure temperature on the room temperature ultimate tensile strength (F_{tu}) of Incoloy 901 alloy bar; longitudinal direction. Exposure up to 1000-hours.



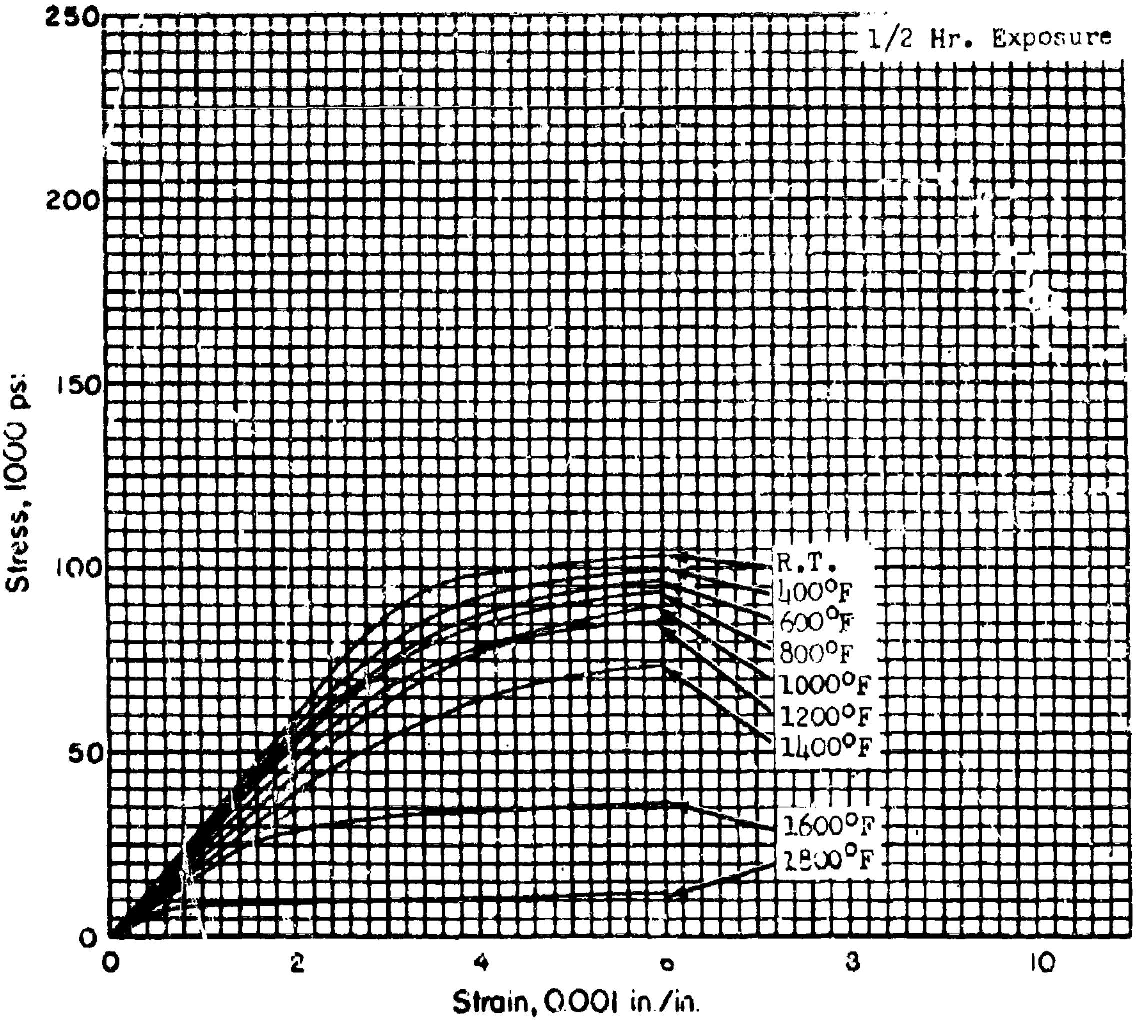
Effect of exposure temperature on the room temperature tensile yield strength (F_{ty}) of Incoloy 901 alloy bar, longitudinal direction. Exposure up to 1000-hours.



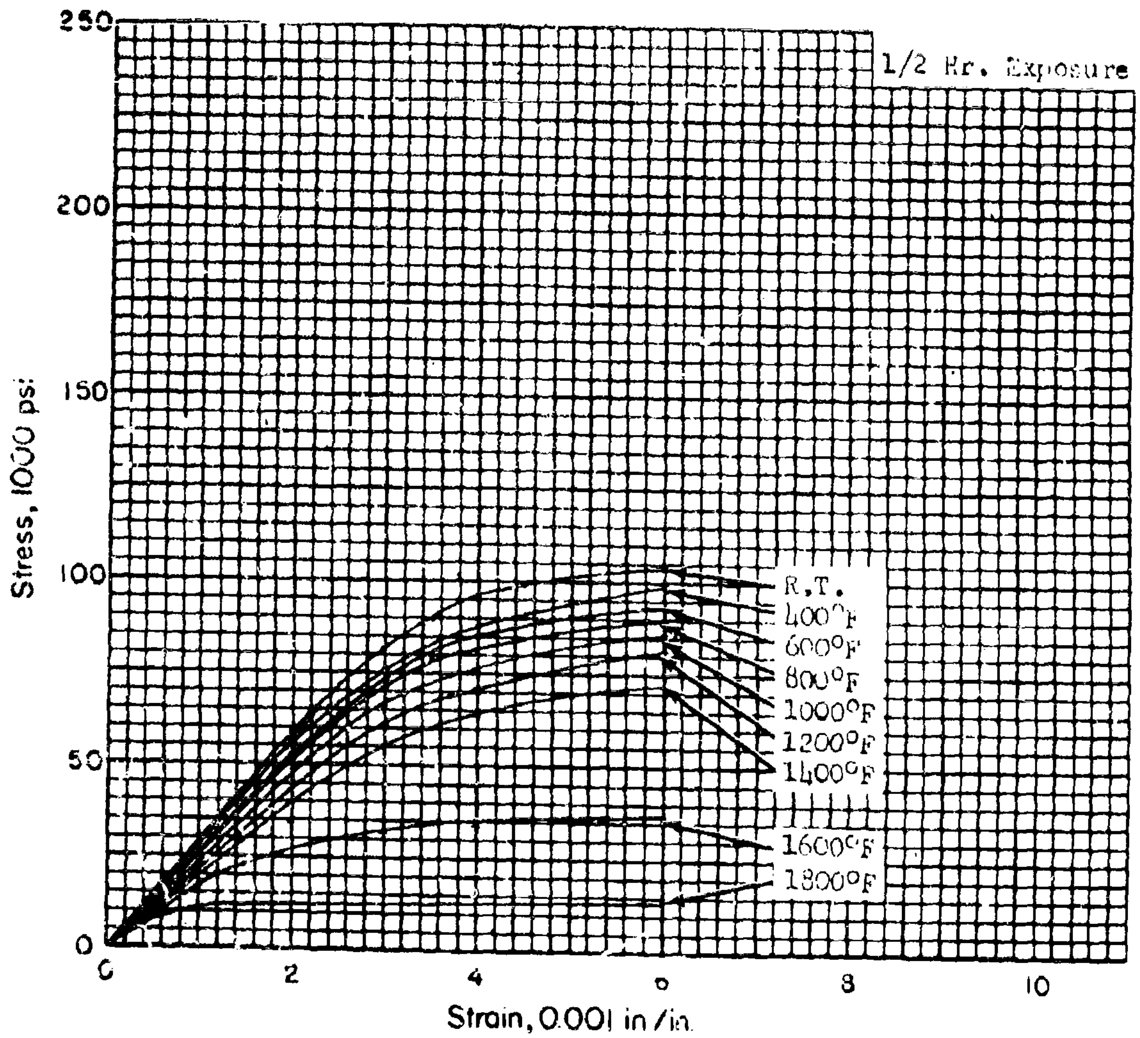
Effect of temperature on the compression yield strength (F_{cy}) of Incoloy 901 alloy bar, longitudinal and transverse directions. Exposure to 1/2-hour.



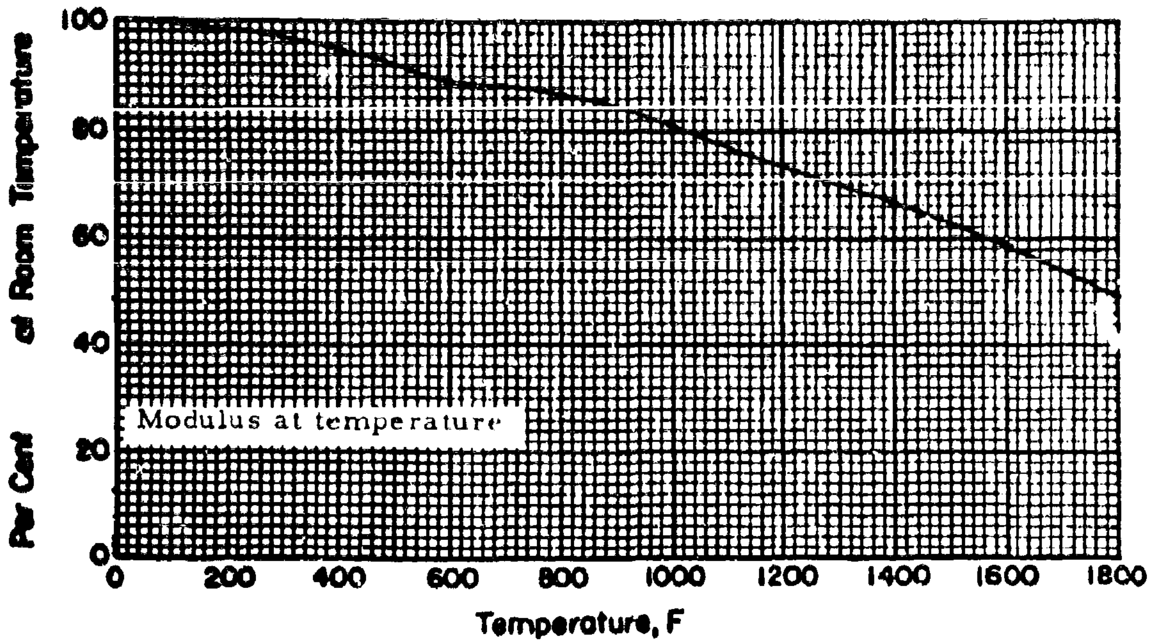
Effect of temperature on the shear ultimate strength (F_{su}) of Incoloy 901 alloy bar, longitudinal and transverse directions. Exposure to 1/2-hour.



Typical tensile stress VS strain curves for Incoloy 901 alloy bar reduced to 'A' basis. Longitudinal direction only.



Typical compressive stress VS strain curves for Incoloy 901 alloy bar reduced to 'A' basis. Longitudinal direction only.



The effect of temperature on the elastic moduli, E and Ec, on Incoloy 901 alloy.

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   Page 248, Appendix III
   Page 249 thru 252, Figures 149 thru 156

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10. "Investigation of Mechanical Properties of Rene' 41", April 1962, ESRMR 137, Republic Aviation Corporation, by C. Shaver

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Appendix A

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REPUBLIC AVIATION CORPORATION
FARMINGDALE, LONG ISLAND, NEW YORK

January 26, 1965

Gentlemen:

SUBJECT: Contract AF 33(657)-8924

On December 1, 1964, ML-TDR-64-116 Research Investigation To Determine Mechanical Properties of Nickel and Cobalt Base Alloys for Inclusion in Military Handbook-5, Volume I, October 1964, was mailed to you in accordance with the distribution list received from the Air Force Systems Command.

Attached hereto is Errata sheet ML-TDR-64-116.

Very truly yours,

REPUBLIC AVIATION CORPORATION

J. A. Weglage, Contracts Administrator
Space Systems and Research

Attach.

ML-TDR-64-116 October 1964

ERRATA - JANUARY 1965

The following corrections are applicable to ML-TDR-64-116 Research Investigation To Determine Mechanical Properties of Nickel and Cobalt Base Alloys for Inclusion in Military Handbook-5, Volume I, October 1964.

PAGE 449

Change - Plate, bar, and forging, B value for F_{ty} should read 142.5 rather than 42.5

PAGE 501

Delete - tentative BAR properties

Add - additional forging properties

Direction	L		T	
Basis	A	B	A	B
F_{tu}, ksi	162.2	168.0	148.4	153.7
F_{ty}, ksi	101.7	111.1	95.8	104.7
F_{cy}, ksi	102.1	111.5		

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